National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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Assessment of direct toxicity and food chain transfer

RIVM Letter report 2015-0139

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Publiekssamenvatting

Evaluatie van de ecologische risicogrenzen voor DDT en Drins in de bodem.
Een beoordeling van de directe toxiciteit en doorvergiftiging in de voedselketen

Het RIVM heeft onderzocht of de ecologische risicogrenzen in bodem voor twee groepen bestrijdingsmiddelen veilig zijn voor roofvogels. Dit betreft zogeheten drins (dieldrin, aldrin, endrin) en DDT, inclusief de bijbehorende afbraakproducten DDD en DDE. Voor endrin en het totaal aan DDT-verbindingen zijn de risicogrenzen aangescherpt om ook roofvogels voldoende te beschermen. Voor dieldrin en aldrin zijn de risicogrenzen daarvoor wel toereikend. Deze informatie kan zowel landelijk als door lokale overheden worden gebruikt bij het afleiden van normen en beslissingen over hergebruik van grond, vooral in groene gebieden.

De onderzochte bestrijdingsmiddelen zijn verboden, maar zitten in bepaalde gebieden van Nederland nog steeds in de bodem. Kleine vogels en zoogdieren krijgen de stoffen binnen via het eten van wormen en andere bodemdieren en geven ze vervolgens door aan grotere roofvogels.

Voor dit onderzoek is recente kennis gebruikt over de mate waarin stoffen via de voedselketen schadelijk kunnen zijn voor grotere organismen. Deze ‘stapeling’ blijkt voor deze stoffen belangrijk en is daarom betrokken bij de berekening van de ecologische risicogrenzen. De huidige risicogrenzen zijn in 2001 afgeleid en zijn alleen gebaseerd op de mate waarin ze direct giftig zijn voor organismen in de bodem. Over de directe giftigheid waren destijds weinig gegevens beschikbaar en er zijn in de huidige studie ook nauwelijks nieuwe gegevens bijgekomen.

Kernwoorden: DDT; drins; ecologische risicogrenzen; doorvergiftiging

Synopsis

Evaluation of ecological risk limits for DDT and drins in soil.
Assessment of direct toxicity and food chain transfer

RIVM evaluates if the current Dutch ecological risk limits for DDT (and its metabolites DDD and DDE), and drins (dieldrin, aldrin, endrin) in soil are protective for predatory birds. For endrin and the sum of DDT-compounds, risk limits are lowered to protect these organisms. For dieldrin and aldrin, the current values give sufficient protection. This information can be used by national and local authorities to set soil standards and to decide on the re-use of soil in green areas.

The use of these pesticides has been banned, but soil residues are still present in certain areas in the Netherlands. The compounds accumulate in birds and mammals via consumption of earthworms and other soil organisms, and are transferred to larger predatory birds.

For this evaluation, up-to-date knowledge on the transfer of these compounds in the food chain to higher animals is used. For both groups of compounds, food chain transfer is a critical factor for the derivation of ecological risk limits in soil. The current values were derived in 2001 on the basis of direct ecotoxicity to soil organisms. Only limited data were available then, and from this study it appears that there still is a lack of relevant data for soil organisms. Improving the risk limits at this point is therefore not possible.

Keywords: DDT; drins; ecological risk limits; food chain transfer

Contents

Summary

In this report, the current Dutch ecological risk limits for DDT and its metabolites, and drins in soil are evaluated. The current values date back to 2001 and are based on a limited dataset. Moreover, only direct ecotoxicity was taken into account whereas for these compounds food chain transfer is highly relevant. The aim of the present research was to investigate if the current ecological risk limits offer adequate protection for the soil ecosystem, considering both direct ecotoxicity and secondary poisoning.

For both groups of compounds a screening of the literature resulted in very limited additional data on direct ecotoxicity to soil organisms. Due to a lack of chronic studies for relevant species, it is not possible to improve the scientific basis of the risk limits for direct ecotoxicity. To overcome this situation, it may be considered to derive risk limits for soil from aquatic data using equilibrium partitioning. However, although some new studies have been published since 2001, new data will not lead to major changes in the outcome as compared to previous evaluations. Moreover, chronic data on relevant endpoints of potentially sensitive species groups are still lacking.

To evaluate the aspect of food chain transfer for both groups of compounds, data on toxicity for birds and mammals were collected and used to derive safe concentrations in bird and mammal food according to current European methodology. From this safe dietary level, an equivalent safe concentration in soil was calculated for worm-eating birds, using information on the accumulation from soil to earthworms. DDT, its metabolites and drins are biomagnifying compounds, meaning that accumulation increases with increasing position in the food chain. As a result, safe values for worm-eating birds may not be protective for higher predators feeding on those birds. Some field studies are available in which residues in soil, worms, birds and eggs were determined. It appears that concentrations of DDT and DDE in small birds and eggs are much higher than in worms from the same location. Based on these field data, an additional safety factor of 10 is proposed to protect predators that feed on small worm-eating birds and/or their eggs. It may be assumed that a similar situation exists for drins, but quantitative information to derive such a factor could not be retrieved in the time span of this project.

Using the information gathered in this report, it appears that the current risk limits for dieldrin and aldrin are likely protective for birds, including predatory species. For DDT, its metabolites and endrin, the current values are likely protective for worm-eating birds, but not for higher predatory birds.

1 Introduction

1.1 Background of the report

Ecological risk limits play an important role in the Dutch soil protection policy. Together with human health related risk limits, they are used for assessment of soil quality in the context of decision making on remediation, re-use of soil and risk management in case of chemical spills or other emergency situations.

The derivation of most risk limits was performed in 2001 [1], mostly based on data from ecotoxicity tests that had been evaluated previously [2-6], but using an adapted methodology.

Since then, risk limits for some (groups of) compounds have been updated, by adding new data to the already available datasets and taking into account methodological developments [7,8], but the majority of the currently used ecological risk limits originates from the 2001-report. Upon request of the Dutch Ministry of Infrastructure and the Environment, it was investigated to what extent the existing ecological risk limits for soil can (should) be improved to meet new scientific developments and to solve practical problems that arise when using those risk limits in practice [9].

As a follow-up, a scoring method was developed to rank the existing ecological risk limits with respect to uncertainty related to data quality and changes in methodology [10]. Based on this evaluation, DDT and its metabolites DDE and DDD and drins (aldrin, dieldrin and endrin) were selected for a closer review. Before focusing on these specific compounds, the following sections give some background information on the risk limits considered in this report and the aspects that are considered most important when discussing the scientific validity of the previously derived risk limits.

1.2 Risk limits considered in this report

The relevant ecological risk limits in the context of this report are the Maximum Permissible Concentration (MPC) and the Serious Risk Concentration (SRC).

The MPC_{soil} is defined as the concentration in soil at which no negative effect on ecosystems is expected [11,12]. The MPC_{soil} is derived considering direct ecotoxicity to soil organisms and/or bacterial or enzymatic processes ($MPC_{soil,\ eco}$), and/or considering secondary poisoning of predatory birds and mammals ($MPC_{soil,\ secpois}$). Considering the protection level and methodology, the $MPC_{soil,\ eco}$ is comparable to a Predicted No Effect Concentration (PNEC) as derived in various international frameworks [13,14]. The derivation of the $MPC_{soil,\ secpois}$ is based on the risk assessment for secondary poisoning as outlined in European guidance [13-15].

The SRC_{soil} is usually derived for direct ecotoxicity to soil organisms and/or processes only. The $SRC_{soil,\ eco}$ is the environmental concentration at which possibly serious ecotoxicological effects on soil organisms and/or processes are to be expected, meaning that 50% of the species or processes is potentially affected. In some cases, secondary poisoning was additionally taken into consideration for derivation of the SRC

[7,16], see further Section 1.4. Detailed guidance for the derivaton of the MPC and SRC for soil is given in [17].
In addition to the MPC_{soil} and SRC_{soil}, an intermediate risk level is presented that represents a limit concentration for the reuse of soil for residential functions in The Netherlands. In line with the methodology described in [18], this intermediate ecological value is set equal to the geometric mean of the ecologically based MPC_{soil} and SRC_{soil}.

1.3 Using ecotoxicity data: data quality and treatment of results

The derivation of ecological risk limits basically follows a four step approach: collection of literature, evaluation of the scientific reliability, selection of relevant endpoints and using the endpoints to derive the risk limits. It can be imagined that if new data were generated since the last evaluation, this may potentially lead to a different result. However, even if this is not the case and the same literature data would be used, newly derived risk limits will differ from those derived in 2001. Re-evaluation of the literature according to current insights may lead to different conclusions regarding the quality of the data, and the way risk limits are derived given a certain dataset has been adapted in several ways during the past years.

1.3.1 Data quality

Regarding data quality, a general observation is that the evaluation of the scientific reliability of individual ecotoxicity studies has received increasing attention over the years. This is partly due to the fact that more established test guidelines have become available, including criteria that can be used to (in)validate test results. It has to be noted, though, that aquatic data seem to be more often rejected than terrestrial tests when studies are re-evaluated according to current insights. This may be due to the fact that for some compounds maintenance of exposure concentrations in aquatic tests is more critical than in confined terrestrial test systems. Both the MPC_{eco} and the SRC_{eco} are preferably based on terrestrial ecotoxicity data. However, when such data are limited or absent, aquatic data may be used to derive risk limits for soil by using equilibrium partitioning. Changes in the quality assessment of aquatic data may thus be important for terrestrial risk limits as well.

1.3.2 Changes in data treatment

Once reliable and relevant ecotoxicity endpoints are selected, the available data can be used in different ways to derive risk limits. If the number of data is limited, an assessment factor is put on the lowest endpoint. If more data are available, statistical extrapolation using Species Sensitivity Distributions (SSDs) can be applied. Changes in the requirements for using the latter were identified as an important factor when considering the uncertainty related to the previously derived risk limits [10]. An SSD displays the fraction of species potentially affected as a function of the exposure concentration. The Hazardous Concentration for 5% and 50% of the species (HC5 and HC50), are used as input for the MPC_{eco} and SRC_{eco}, respectively.

In 2001, SSDs were applied when data for at least four taxonomic groups were available[1], regardless of the trophic levels represented in the dataset. The HC5 and HC50 were used without any additional assessment factors. With the implementation of the European Technical Guidance Document (TGD) for risk assessment of new and existing substances in 2003 [13], the requirements for performing SSDs have been extended. At present, SSDs can only be performed when at least 10 (preferably 15) values are available for at least eight different taxonomic groups, representing primary producers, and primary and secondary consumers. For the aquatic compartment, it is specified in detail which are the required taxonomic groups. This is not the case for soil, but the requirements with respect to the number of data and the inclusion of at least three trophic levels are considered to be the same. As a consequence, application of SSDs for terrestrial species is possible in rare cases only.

For the SRC_{eco}, whether or not performing an SSD is not a major change if No Observed Effect Concentrations (NOECs) are present for at least two trophic levels. The 50th percentile of the SSD that was used previously, is equal to the geometric mean of the NOECs that will be used now. However, when less than two taxonomic groups are present and/or the NOECs represent a single trophic level, acute data will be considered as well and an additional comparison with the equilibrium partitioning method will be made. In 2001, the comparison with equilibrium partitioning based values was almost always made and the lower value was chosen.

1.4 Importance of secondary poisoning

The above discussed changes in data evaluation and application of SSDs concern risk limits based on direct ecotoxicity to soil organisms. In view of the high bioaccumulation potential of DDT and related compounds, secondary poisoning of predatory birds and mammals should be taken into account when assessing the impact of soil contamination on ecosystem health. However, in line with previous evaluations [6,19,20], it was concluded in the 2001-report that secondary poisoning was not critical for the derivation of the MPC when applying the then prevailing methods [1]. However, based on updated information on the accumulation of DDT by earthworms, it was concluded in 2002 that inclusion of secondary poisoning would potentially be critical for derivation of the MPC [16]. At the level of the SRC, inclusion of secondary poisoning would lead to a value similar to the SRC_{eco} derived in the 2001-report, which was based on direct ecotoxicity only [16].

As for the above described changes in performing SSDs, also for secondary poisoning important developments in methodology have been made since 2001-2002. In general, the evaluation of the bird and mammal studies with respect to quality has not been changed to a great extent, and endpoints obtained in the past are most often still considered valid upon re-evaluation. However, the way these data are used according to the TGD [13] differs from that used in the above mentioned evaluations. Assessment factors are applied depending on the duration of the studies, and conversion factors are used to translate toxicity endpoints based on dietary doses into values based on

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[1] e.g. bacteria, fungi, insects and earthworms

concentrations in food. Moreover, risk limits based on secondary poisoning have been calculated in the past using one combined dataset in which data on direct ecotoxicity and secondary poisoning were combined, or using separate datasets [16]. At present treating secondary poisoning and direct ecotoxicity separately is considered most appropriate, and the route leading to the lowest risk limit is used to set the final value [17]. These methodological changes will lead to risk limits for secondary poisoning that are potentially lower than those derived previously, even if the same input data on bird and mammal toxicity are used. Recently, an alternative methode has been developed that uses an energy-based approach to convert toxicity data for birds and mammals obtained with laboratory diet to corresponding values in wildlife food [21]. It appeared, however, that the available data do not allow to further explore this method in this report (see section 2.3.4.1).

1.5 Aim of the present report, readers guide

The aim of the present research is to investigate if the current ecological risk limits offer adequate protection for the soil ecosystem, considering both direct ecotoxicity and secondary poisoning. DDT and related compounds are discussed in Chapter 2. In section 2.1, the assessment of direct ecotoxicity is evaluated first, a closer look is taken at the underlying data that were used in 2001, and the options for improving the dataset for direct ecotoxicity are discussed on the basis of a literature screening on new terrestrial and aquatic ecotoxicity data. In section 2.2, the assessment of secondary poisoning is elaborated on, with an overview of previously made evaluations (section 2.2.1), and an additional assessment for worm-eating birds and mammals and higher predators (section 2.2.3). Section 2.3 gives the summary and conclusions on DDT and metabolites. Chapter 3 follows the same order for drins.
Chapter 4 summarises the results of the evaluation and discusses the implications for the derivation of the MPC_{eco} and SRC_{eco} of these compounds.

2 DDT and metabolites

2.1 Assessment of direct ecotoxicity

2.1.1 *Direct ecotoxicity to soil organism*

2.1.1.1 Previous assessment

In 2001, no data were available on direct ecotoxicity of DDE and DDD to soil organisms [1]. For DDT the data were taken from a previous RIVM-evaluation (and Annex) prepared by Van de Plassche in 1994 [6,22]. Terrestrial data in that report were taken from an earlier RIVM-report that was published in 1990 by Denneman and Van Gestel [4]. The dataset consists of a single acute LC50-value of 10 mg/kg$_{\text{dwt soil}}$ for the cricket *Gryllus pennsylvanicus*. This value is the geometric mean of 12 values from tests in different soil types, and is expressed on the basis of Dutch standard soil with 10% organic matter (OM). The MPC$_{\text{eco}}$ of 0.01 mg/kg$_{\text{dwt soil}}$ was derived using this value with an assessment factor (AF) of 1000, the SRC$_{\text{eco}}$ was set to 1 mg/kg$_{\text{dwt soil}}$ using an AF of 10. Both values are expressed on the basis of dry weight (dwt) soil for Dutch standard soil containing 10% organic matter (OM). The result of the equilibrium partitioning method (see section 2.1.2) was less critical than this direct value.

2.1.1.2 Evaluation of additional data

To evaluate the options for adding new soil ecotoxicity values to the dataset, the Ecotox database of the United States Environmental Protection Agency (US EPA) [23] and the US EPA report on ecological soil screening levels (Eco-SSL) for DDT and metabolites [24], were screened for additional ecotoxicity data from relevant tests.

The US EPA Ecotox database did not contain any additional relevant data for DDE and DDD. Most entries for DDT in the US EPA Ecotox database concern studies with spray application, expressed in a weight per area basis. These data were not further considered. Of the remaining chronic data (test duration of 12 days or longer) one relevant study was retrieved in which micro-organisms, plants, springtails and earthworms were tested [25]. Resulting chronic EC50-values were all > values, except for an EC50 of 588 mg/kg$_{\text{dwt soil}}$, for reproduction of the earthworm *Eisenia fetida* in a sandy soil with 1% organic carbon (≈ 1.7% OM), and an EC50 of 950 mg/kg$_{\text{dwt soil}}$ for the springtail *Folsomia candida* in a silty soil with 1.7% organic carbon (≈ 2.89% OM). From the data in this paper, EC10-values of 47.5 and 51 mg/kg$_{\text{dwt soil}}$ could be fitted for reproduction of *E. fetida* and *F. candida*, respectively. Expressed on the basis of Dutch standard soil with 10% OM, these EC10-values would be equal to 280 and 176 mg/kg$_{\text{dwt soil}}$.

The US EPA Eco-SSL report [24] cites two reliable studies with plants, one of which could be retrieved. From the data in this study [26], a 13-weeks EC10 of 7.3 mg DDT/kg$_{\text{dwt soil}}$ was estimated for growth of the common bean *Phaseolus aureus* in a soil with 0.53% organic carbon (≈ 0.91% OM). This is equivalent to 80 mg/kg$_{\text{dwt soil}}$ in Dutch standard soil with 10% OM. According to the abstract of the other study [27], exposure to DDT at 5 to 50 mg/kg$_{\text{dwt soil}}$ had no effect on germination, seedling emergence and early growth of cotton (*Gossypium hirsutum*), soybean (*Glycine max*), corn (*Zea mays*) and wheat (*Triticum aestivum*) in a soil with 0.85% organic carbon, the NOEC would thus be ≥ 341 mg/kg$_{\text{dwt soil}}$ at 10% OM. The available ecotoxicity data for soil organisms are presented in Table 1.

Table 1 Available data on the ecotoxicity of DDT to soil organisms. Values are given for Dutch standard soil containing 10% organic matter.

Species	acute L(E)C50 [mg/kg$_{\text{dwt soil}}$]	chronic EC10 [mg/kg$_{\text{dwt soil}}$]
Insects		
Gryllus pennsylvanicus	10	
Folsomia candida		176
Earthworms		
Eisenia fetida		280
Plants		
Phaseolus aureus		80
Gossypium hirsutum		≥ 341
Glycine max		≥ 341
Zea mays		≥ 341
Triticum aestivum		≥ 341

The chronic EC10-values for springtails, earthworms and plants are much higher than the acute LC50 for the cricket, indicating that none of these represents a sensitive species group. This limits the usefulness of the chronic data for derivation of the MPC$_{\text{soil, eco}}$ and SRC$_{\text{soil, eco}}$ to a great extent. Because chronic data for a potentially sensitive taxon are missing, the MPC$_{\text{soil, eco}}$ should still be derived on the basis of the acute value. In the absence of chronic data for sensitive species, taking the geometric mean of the EC10-values would result in a bias in the derivation of the SRC$_{\text{eco}}$. Due to a lack of data, the US EPA did not derive Eco-SSL for DDT and metabolites based on plants or invertebrates [24].

2.1.1.3 Conclusion on direct ecotoxicity to soil organisms

From the above it is concluded that for DDT, it is possible to improve the dataset for soil organisms that was used in 2001, by re-assessing the quality of the “old” studies and by addition of new studies that were performed after 1994. However, the relevance of the new data for soil organisms is limited, because they were derived for species that are much less sensitive than the species already included in the dataset. New data for DDE and DDD are not available. It is concluded that a revision of risk limits on the basis of direct ecotoxicity data for soil organisms is not possible.

2.1.2 Aquatic ecotoxicity data used for equilibrium partitioning

2.1.2.1 Previous assessments and additional data for DDT

In 2001 [1], risk limits for DDT based on direct ecotoxicity for soil organisms were compared with those derived from aquatic data by equilibrium partitioning (EqP) because of the limited data for soil organisms. The dataset of the 1994-report [22] consisted mainly of acute data, and only few chronic studies were available. Data for fresh- and saltwater species were combined. The lowest acute L(E)C50 was 0.63 µg/L for *Daphnia pulex*, the lowest NOEC-value was 0.05 µg/L for

D. magna. The geometric mean of the chronic NOEC-values was 1.7 µg/L, the geometric mean L(E)C50 was 4.3 µg/L. Using an AF of 10 on the latter, the $SRC_{water, eco}$ was derived as 0.43 µg/L. From this value, an $SRC_{soil, eco}$ of 10 mg/kg was derived using a partitioning coefficient of 4.35 (log-value, taken from [28]). Because this value is higher than the value of 1 mg/kg based on direct ecotoxicity for soil organisms (see above), the latter was chosen as the final $SRC_{soil, eco}$. An $MPC_{water, eco}$ for direct ecotoxicity of 0.005 µg/L (5 ngL/) was derived in 1994, based on a NOEC of 0.05 µg/L for *Daphnia magna* with an AF of 10. The $MPC_{water, secpois}$ based on secondary poisoning was 0.00044 µg/L (44 ng/L), and this value was taken as the final MPC_{water}. This value was not used for further calculation of the MPC for soil, the $MPC_{soil, eco}$ was set at the above mentioned value of 0.01 mg/kg (see 2.1.1).

The acute dataset for DDT used in 1994 and 2001 includes L(E)C50-values for 44 freshwater species and for 26 saltwater species, including algae, crustaceans, insects, molluscs, fish and amphibians. The chronic dataset for DDT includes NOECs for two freshwater species and seven saltwater species, including algae, crustaceans and fish. Except for the chronic fish-study, analysis of test concentrations was not performed, which at present would be reason to reject the results. Moreover, the chronic NOECs for daphnids originate from a 14-days study and were estimated by dividing L(E)C50-values by 10. This would mean that from the previously used data, only the single NOEC for fish of 0.35 µg/L would probably be selected after re-evaluation of the old dataset.

Similar to what was done for soil, the US EPA Ecotox database was screened for (additional) data on aquatic ecotoxicity. The database contains data for technical DDT and o′,p′-DDT. Data were first filtered for tests in which concentrations were verified. The remaining dataset was split into acute data from tests lasting 5 days or less, and chronic data from tests lasting 7 days and longer.
The resulting acute dataset (see Appendix 1, Table A1.1) contains about 60 potentially relevant acute data (LC50, EC50) originating from 14 literature references, only few of which were published later than 1994. The lowest relevant acute endpoints per species are shown in Table 2. The lowest value of this selection is a 4-days LC50 of 0.17 µg/L for the crustacean *Hyalella azteca* [29], which is about 3.5 times lower than the previously lowest geometric mean EC50 of 0.63 µg/L for the crustacean *Daphnia pulex*, but only two times lower than the lowest individual EC50 of 0.36 µg/L reported for this species (see footnote c to table A8.2 in [1]). the geometric mean of the acute values is 4.4 µg/L, which is similar to the value of 4.3 µg/L derived in 2001 [1].

Table 2 Acute aquatic ecotoxicity data for DDT included in the US EPA Ecotox database. Lowest relevant endpoint per species from short-term studies (≤ 5 days) in which concentrations were measured. Marine species are indicated with sw = saltwater.

Species	Exposure duration [h]	L(E)C50 [µg/L]
Crustaceans		
Ceriodaphnia dubia	48	0.83
Crangon septemspinosa (sw)	96	0.4
Daphnia pulex	48	0.4
Gammarus fasciatus	120	0.6
Hyalella azteca	96	0.17
Orconectes nais	96	100
Palaemonetes kadiakensis	120	1
Insects		
Baetis sp.	48	12
Chironomus dilutus	96	0.71
Ischnura verticalis	96	56
Fish		
Barbus dorsalis	96	48
Encrasicholina purpurea	12	1
Gambusia affinis	96	20
Ictalurus punctatus	48	12
Kuhlia sandvicensis (sw)	96	3.9
Lepomis macrochirus	48	6
Misgurnus anguillicaudatus	24	350
Oncorhynchus mykiss	48	5
Oreochromis mossambicus	96	7
Pimephales promelas	96	8.5
Poecilia reticulata	96	3
Echinoderms		
Strongylocentrotus droebachiensis (sw)	80 min	3

When selecting chronic data from those tests in which chemical analysis was performed, 50 potentially relevant endpoints were found for four different species (crustaceans, insects, fish, and a mollusc), originating from eight references (see Appendix 1, Table A1.2). The lowest value from these new data is a 10-days LC50 of 0.07 µg/L for *H. azteca* [30], which is very similar to the 10-days LC50 of 0.094 µg/L obtained for the same test duration in a more recent study [31]. For another crustacean species, *Diporeia* sp., an LC50 of 0.26 µg/L and EC50 of 0.07 µg/L for narcosis are reported from a 28-days test [29]. Unfortunately, the US EPA dataset does not report NOEC or EC10 values for these species. However, from information provided in the papers, LC10-values could be estimated. The chronic endpoints that were collected from the US EPA Ecotox database and estimated LC10-values are presented in Table 3. A 10-days LC10 of 0.04 µg/L could be estimated for *H. azteca*, while for *Diporeia* sp. the 28-days LC10 was estimated as 0.19 µg/L. If for this species the ratio between the 28-days EC50 for narcosis and the LC50 for mortality (0.07/0.26) is also valid at the 10%-effect level, the 28-days EC10 for narcosis would be 0.05 µg/L. This is similar to the 10-days LC10 of 0.04 µg/L for *H. azteca*. It should be noted that the endpoints for crustaceans and insects only refer to mortality and immobility. Potentially sensitive endpoints such as growth and reproduction are not included. The geometric mean of the new NOEC/LC10-values for DDT is 0.31 µg/L.

Table 3 Chronic aquatic ecotoxicity data for DDT included in the US EPA Ecotox database, selection from long-term studies (≥ 5 days) in which concentrations were measured. LC10-values were not included in the database, but estimated using data of the authors. Marine species are indicated with sw = saltwater.

Compound/ Species	Exposure duration [d]	NOEC	$LC10^{\#}$ [µg/L]	LC50 [µg/L]	EC50 [µg/L]	Ref.
Crustaceans						
Ceriodaphnia dubia	7	1.74				
Diporeia sp.	28		0.19	0.26	0.07	[29]
Hyalella azteca	10		0.04	0.094^{a}	-	[31]
Insects						
Chironomus dilutus	10		0.22	0.49	0.36	[31]
Fish						
Oryzias latipes	14	0.5				
Molluscs						
Crassostrea virginica (sw)	84	0.6				

\# not included in US EPA Ecotox database, value derived from original reference
a: a lower LC50 of 0.07 µg/L is included for this species in the US EPA Ecotox database [23], but no LC10 could be derived from this reference

2.1.2.2 Previous assessments and additional data for DDE and DDD

Because data on direct ecotoxicity to soil organisms were absent, the $SRC_{soil,\ eco}$ for DDE and DDD was based on equilibrium partitioning using aquatic data.

For DDE, the dataset of the 1994-report [22] consisted of acute L(E)C50-values for seven marine and freshwater species (crustaceans, molluscs, fish, and flatworms), and one single 14-days chronic NOEC of 0.1 µg/L for the marine crustacean *Nitocra spinipes*. The geometric mean of the acute data for DDE was 50 µg/L, and the $SRC_{water,\ eco}$ was set equal to the single NOEC of 0.1 µg/L, the $MPC_{water,\ eco}$ to 0.001 µg/L. Based on these values, an $SRC_{soil,\ eco}$ of 1.3 mg/kg and $MPC_{soil,\ eco}$ of 0.013 mg/kg were derived using equilibrium partitioning. Again the former MPC-value based on secondary poisoning was retained as the final MPC_{water}.

For DDD, the 1994-dataset [22] contained acute values only, including L(E)C50-values for 18 marine and freshwater species (algae, crustaceans, an insect, a mollusc, fish and amphibians). The geometric mean of acute data was 38 µg/L, and the $SRC_{water,\ eco}$ was set to 3.8 µg/L. The $MPC_{water,\ eco}$ was set to 0.024 µg/L using the lowest L(E)C50 of 2.4 µg/L for *Penaeus duorarum* with an AF of 100. Based on these risk limits for water, the $SRC_{soil,\ eco}$ and $MPC_{soil,\ eco}$ were set to 34 and 0.021 mg/kg using equilibrium partitioning. Note that the final MPC_{water} was kept at the former value of 44 ng/L derived for DDT on the basis of secondary poisoning (see 2.2.1).

As for DDT, analytical verification of test concentrations was not performed in the test used in 1994 and 2001. Only few studies were performed using a renewal or flow-through system, and most studies would nowadays not be accepted as valid.

Additional aquatic endpoints for DDE and DDD from tests with analytical verification of test concentrations were collected from the US EPA Ecotox database as described above for DDT. For both compounds, acute L(E)C50-values from short-term tests based on measured concentrations were only available for the crustacean *H. azteca* and the insect *Chironomus dilutus*.
For DDE, L(E)C50-values of 4.57 and 22.3 µg/L are reported for *H. azteca* and *C. dilutus* [31]. The LC50 of 4.57 µg/L is nearly two times higher than the previously used lowest LC50 of 2.5 µg/L for *N. spinipes* [22]. The geometric mean of the two new values is 10 µg/L, which is five times lower than the previously used geometric mean of 50 µg/L.
For DDD, reported 4-days L(E)C50-values for *H. azteca* and *C. dilutus* are 0.82 µg/L and 0.22 µg/L, respectively [31]. This latter value is a factor of 10 lower than the lowest LC50 of 2.4 µg/L for *P. duorarum* that was used previously. The geometric mean of the new L(E)C50-values for DDD is 0.40 µg/L, which is derived, which is almost 100 times lower than the previously used geometric mean of 38 µg/L.

For the long-term tests with DDE and DDD included in the US EPA Ecotox database, only L(E)C50-values are reported. However, from the data included in the above mentioned two references [29,31], LC10-values could be derived for *H. azteca*, *C. dilutus* and *Diporeia* sp. (DDD only). The estimated LC10-values are shown in Table 4, together with the LC50 and EC50-values reported by the authors for the same tests. The geometric mean LC10 is 3.6 µg/L for DDE and 0.40 µg/L for DDD.

Table 4 Chronic aquatic ecotoxicity data for DDD and DDE included in the US EPA Ecotox database, selection from long-term studies (≥ 5 days) in which concentrations were measured. LC10-values were not included in the database, but estimated using data of the authors.

Compound/ Species	Exposure duration [d]	LC10# [µg/L]	LC50 [µg/L]	EC50 [µg/L]	Ref.
DDE					
Crustaceans					
Hyalella azteca	10	2.30	3.21	-	[31]
Insects					
Chironomus dilutus	10	5.71	8.65	7.81	[31]
Chironomus tentans	10		3.0		[30]
Annelids					
Lumbriculus variegatus	10		>3.27		[30]
DDD					
Crustaceans					
Diporeia sp.	28	0.76	1.96	<0.9	[29]
Hyalella azteca	10	0.17	0.30^b	-	[31]
Insects					
Chironomus dilutus	10	0.17	0.42	0.23	[31]
Chironomus tentans	10	-	0.18	-	[30]

not included in US EPA Ecotox database, values derived from original reference
b: a lower LC50 of 0.19 µg/L for this species is included in the US EPA Ecotox database [23], but no LC10 could be derived from this reference

When considering using these values, some remarks should be made. First of all, similar to DDT it should be noted that EC50-values reported by the authors for *Diporeia* sp. and *C. dilutus* are lower than the corresponding LC50-values, but EC10 values could not be calculated. Furthermore, lower LC50-values were reported for *H. azteca* as compared to the studies that were used for LC10-estimation. Most important, the endpoints considered here only involve mortality and immobility. Potentially more sensitive endpoints such as growth or reproduction are not included, and the previously used lowest 14-days NOEC of 0.1 µg/L for effects of DDE on reproduction of the marine crustacean *N. spinipes* is over 20 times lower than the lowest LC10 derived here. This 'old' NOEC would most likely be retained, since renewal of test medium was applied. This leads to the conclusion that the LC10-values as derived here might not represent the most sensitive endpoint per taxonomic group.

2.1.2.3 Conclusions on direct ecotoxicity to aquatic organisms

Additional aquatic data are available that may be used for derivation of risk limits for soil by means of equilibrium partitioning. The impact of the additional aquatic data for DDT is likely limited when acute data are used for derivation of the $SRC_{water, eco}$, since the geometric mean of the new acute data is similar to the previously derived value (4.4 vs. 4.3 µg/L). The geometric mean of the new chronic data for DDT is lower than used before (0.31 vs. 1.7 µg/L), and the lowest LC10-value from the new data is about a factor of 10 lower than the lowest valid NOEC from the old dataset (0.04 vs. 0.35 µg/L). This would potentially lead to lower $SRC_{water, eco}$ and $MPC_{water, eco}$-values. It should be noted that potentially sensitive endpoints such as growth and reproduction are not available.

For DDE and DDD, additional aquatic data are available that may be used for derivation of risk limits for soil using equilibrium partitioning. These additional aquatic data may lead to a substantial lower geometric mean L(E)C50. However, in contrast to the dataset for DDT, some of the previously used studies with DDD and DDE might pass the current quality assessment because renewal or flow-through systems were applied. When these higher acute L(E)50-values from the old dataset are retained, the geometric mean and the resulting $SRC_{water,\ eco}$ will be higher too and the difference with the old value might be less. Considering the chronic values, it is noted that relatively low values were found for DDD. The geometric mean LC10 of 0.40 μg/L for DDD based on new data is about a factor of 100 lower than the $SRC_{water,\ eco}$ of 38 μg/L that was previously derived on the basis of acute data. In contrast, the additional LC10-values found for DDE are much higher than the previously derived NOEC, and the $SRC_{water,\ eco}$ based on the geometric mean NOEC/LC10-values would at least be 10 times higher than before.

At the level of the $MPC_{water,\ eco}$, the impact of the new data is expected to be limited. For DDD, the availability of chronic data would allow for using a lower assessment factor. For DDE, accepting the previously used lowest NOEC of 0.1 μg/L would mean that the $MPC_{water,\ eco}$ remains unchanged.

2.2 Assessment of secondary poisoning

2.2.1 Introduction

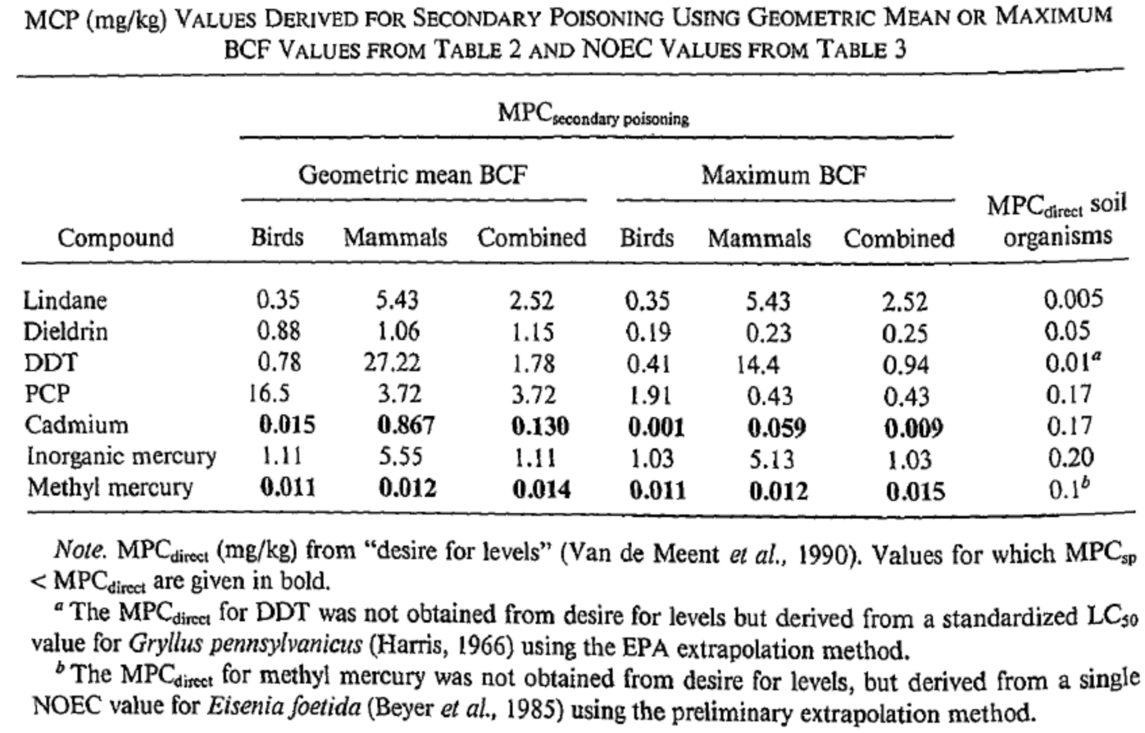
As indicated above in section 1.4, the question on the relevance of secondary poisoning for soil risk limits has been addressed several times in the past. It was also mentioned in that section that the methodology regarding the treatment of bird and mammal data has been brought in line with European guidance, and that additional guidance has been developed recently. In this chapter, the previous evaluations are briefly summarised and it is investigated if additional data and new guidance will change the conclusions that were drawn previously. Section 2.2.2 summarises the previous assessments from 1991 and 1994, which involved the assessment of a simplified terrestrial food chain (soil → worm → worm eating bird or mammal) [19,20], and a more complex assessment based on energy demands and including higher predators [32,33]. The assessment using new data is presented in section 2.2.3.

2.2.2 Previous assessments

2.2.2.1 Risks for worm eating birds and mammals

The first evaluation of secondary poisoning of DDT and metabolites in the context of Dutch standard setting for soil was made in an RIVM-report that was published in 1991 by Romijn et al. [20]. In this report, an MPC_{soil} was derived for worm-eating bird and mammals, by dividing the NOEC for birds and/or mammals by a bioconcentration factor (BCF) for worms (nowadays often referred to as Biota to Soil Accumulation Factor, BSAF). Calculations were performed for birds and mammals alone or combined, the NOECs were derived by statistical extrapolation, using NOECs for individual species. A geometric mean and maximum BSAF for worms of 0.27 and 0.51 $kg_{dwt\ soil}/kg_{wwt\ worm}$ were used, based on five datapoints from combined laboratory and field tests and corrected to a standard soil with 10% OM. The results are presented in the table below, taken from the publication based on the 1991-report [19].

Table 5 $MPC_{soil,\ secpois}$ derived by Romijn et al. [19,20] using NOEC-data for birds and mammals and BCF (BSAF)-values for worms. The NOECs for birds and mammals were based on statistical extrapolation. The BSAFs used were 0.27 (geometric mean) and 0.51 $kg_{dwt\ soil}/kg_{wwt\ worm}$, both corrected to standard soil with 10% organic matter. Table copied from [19].



MCP (mg/kg) VALUES DERIVED FOR SECONDARY POISONING USING GEOMETRIC MEAN OR MAXIMUM BCF VALUES FROM TABLE 2 AND NOEC VALUES FROM TABLE 3

	$MPC_{secondary\ poisoning}$						
	Geometric mean BCF			Maximum BCF			
Compound	Birds	Mammals	Combined	Birds	Mammals	Combined	MPC_{direct} soil organisms
Lindane	0.35	5.43	2.52	0.35	5.43	2.52	0.005
Dieldrin	0.88	1.06	1.15	0.19	0.23	0.25	0.05
DDT	0.78	27.22	1.78	0.41	14.4	0.94	0.01[a]
PCP	16.5	3.72	3.72	1.91	0.43	0.43	0.17
Cadmium	**0.015**	**0.867**	**0.130**	**0.001**	**0.059**	**0.009**	0.17
Inorganic mercury	1.11	5.55	1.11	1.03	5.13	1.03	0.20
Methyl mercury	**0.011**	**0.012**	**0.014**	**0.011**	**0.012**	**0.015**	0.1[b]

Note. MPC_{direct} (mg/kg) from "desire for levels" (Van de Meent *et al.*, 1990). Values for which $MPC_{sp} < MPC_{direct}$ are given in bold.

[a] The MPC_{direct} for DDT was not obtained from desire for levels but derived from a standardized LC_{50} value for *Gryllus pennsylvanicus* (Harris, 1966) using the EPA extrapolation method.

[b] The MPC_{direct} for methyl mercury was not obtained from desire for levels, but derived from a single NOEC value for *Eisenia foetida* (Beyer *et al.*, 1985) using the preliminary extrapolation method.

In the same publication, also an uncorrected geometric mean BCF (BSAF) of 3.29 $kg_{dwt\ soil}/kg_{wwt\ worm}$ is presented. This value is based on a much larger dataset of 23 laboratory and field studies with 10 species, individual BSAFs range from 0.09 to 21.9 $kg_{dwt\ soil}/kg_{wwt\ worm}$. Because organic matter content was not reported for all studies, a correction could not be applied.

In 1994, the same dataset was used by Van de Plassche et al. to make the comparison with direct ecotoxicity at the level of the MPC [6,22]. In this report, default BSAFs for worms of 1 and 10 $kg_{dwt\ soil}/kg_{wwt\ worm}$ were used. Data for birds and mammals were treated separately as before, but also put into a combined dataset together with data for direct ecotoxicity. The results for p,p'-DDT are shown below in Table 6. For o,p'-DDT, p,p'-DDD, and p,p'-DDE, the MPC for secondary poisoning was not calculated because comparison with direct ecotoxicity could not be made in the absence of data. The final MPC_{soil} for DDT as well as for DDD and DDE was set at 0.01 $mg/kg_{dwt\ soil}$, based on direct ecotoxicity. In 2002, an $SRC_{soil,\ secpois}$ of 1.1 $mg/kg_{dwt\ soil}$ was derived for DDT using combined data on birds and mammals [16].

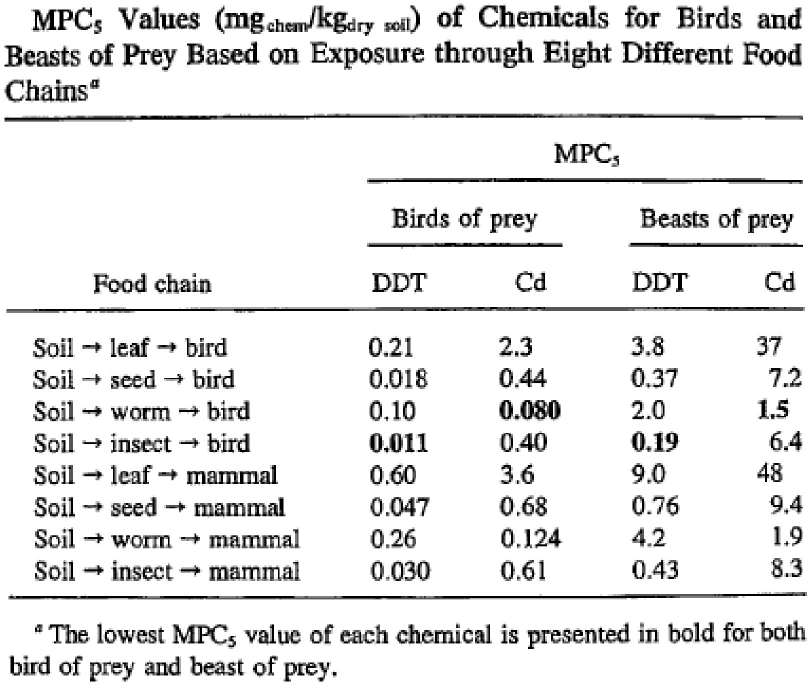
Table 6 Overview of MPC-values for DDT derived in 1994 [6,22]. All values in mg/kg$_{dwt\ soil}$.

MPC$_{soil,\ eco}$	MPC$_{soil,\ secpois}$ birds	MPC$_{soil,\ secpois}$ mammals	MPC$_{soil,\ secpois}$ birds/ mammals	MPC$_{soil}$ eco + secpois	MPC$_{soil}$ EqP
0.01	0.048	1.7	0.11	0.01	0.0094

2.2.2.2 Foodweb approach

Also in 1994, an RIVM-report was published by Jongbloed et al. in which risk limits for soil were derived for various top predators using a foodweb approach considering exposure of birds and mammals to different types of food [32]. For this, the bird and mammal toxicity data of Romijn et al. were supplemented with new data. These data were converted to NOECs for top predators applying correction factors for the differences in energy demand and assimilation efficiency between free living and laboratory animals, and differences in caloric content between laboratory food and wild prey. Geometric mean bioaccumulation factors (BAFs) were used to describe the accumulation of DDT from soil by invertebrates and plants, and the accumulation from food by birds and mammals. For earthworms, a geometric mean BSAF of 0.17 kg$_{dwt\ soil}$/kg$_{wwt\ worm}$ is reported, based on six laboratory and field experiments. Further details could not be found in the appendices of the report and associated publication [32,33]. Information on diet composition and caloric content of food was used to calculate soil-based BAFs for top predators, which were used to back-calculate the NOECs for these species to an MPC$_{soil}$. The resulting MPC-values for different food chains and for specific predator species are summarised in the table below, taken from the publication of this work in 1996 [33].

Table 7 MPC$_{soil,\ secpois}$ derived by Jongbloed et al. [32,33] using converted NOEC-data for top predators and BAF-values for different food sources. Table copied from [33].



MPC$_5$ Values (mg$_{chem}$/kg$_{dry\ soil}$) of Chemicals for Birds and Beasts of Prey Based on Exposure through Eight Different Food Chains[a]

	MPC$_5$			
	Birds of prey		Beasts of prey	
Food chain	DDT	Cd	DDT	Cd
Soil → leaf → bird	0.21	2.3	3.8	37
Soil → seed → bird	0.018	0.44	0.37	7.2
Soil → worm → bird	0.10	**0.080**	2.0	**1.5**
Soil → insect → bird	**0.011**	0.40	**0.19**	6.4
Soil → leaf → mammal	0.60	3.6	9.0	48
Soil → seed → mammal	0.047	0.68	0.76	9.4
Soil → worm → mammal	0.26	0.124	4.2	1.9
Soil → insect → mammal	0.030	0.61	0.43	8.3

[a] The lowest MPC$_5$ value of each chemical is presented in bold for both bird of prey and beast of prey.

When comparing the results of the foodweb model of Jongbloed et al. (Table 7) on the one hand with the calculations of Romijn et al. (see Table 5) on the other hand, it can be seen that the foodweb model with top predators results in lower MPC-values than considering only worm eating birds and mammals. For the short food chain, MPC-values are 0.41 and 0.78 $mg/kg_{dwt\ soil}$ for birds and 14.4 and 27.2 $mg/kg_{dwt\ soil}$ for mammals, depending on the BSAF used (see Table 5). When extending the worm-based food chain with top predators, the MPC-values are 0.1 and 0.26 $mg/kg_{dwt\ soil}$ when based on predatory birds and 2.0 and 4.2 $mg/kg_{dwt\ soil}$ for predatory mammals (Table 7). However, because of the differences in underlying methodology, it is not possible to translate these differences in a simple correction factor that can be used to account for biomagnification to higher food chain levels.
The principle of using energy demand of birds and mammals and caloric content in food to estimate safe levels has been implemented for worm-eating birds and mammals in the risk assessment methodology for the authorisation of plant protection products [34]. The extended foodweb approach has never been officially adopted for deriving risk limits for soil.

2.2.3 *Evaluation and additional assessment for DDT and related compounds*

2.2.3.1 General methodology

The current methodology for the derivation of an $MPC_{soil,\ secpois}$ for worm-eating birds and mammals is described in Van Vlaardingen and Verbruggen [17] and is based on European guidance [13,15]. Toxicity data for birds and mammals are collected and the results are expressed on the basis of a dietary concentration in mg/kg_{fd}. If the results of a study are presented as a daily dietary dose on the basis of body weight (bw), the corresponding dietary concentration is recalculated using the reported information on food intake and body weight or default conversion factors. After conversion, the resulting NOEC (sometimes also indicated as a No Observed Adverse Effect Concentration, NOAEC) is divided by the appropriate assessment factor, considering the duration of the study. This assessment factor also includes a correction for the difference in caloric content of laboratory food as compared to field prey, for which a correction factor of 3 is used. In fact, with this factor it is assumed that in the field a bird or mammal has to eat 3 times as much as compared to the lab to cover its energy demand. The lowest value is used as the $MPC_{oral,\ bird}$ or $MPC_{oral,\ mammal}$, which denotes the concentration in earthworms that will not lead to negative effects on birds and mammals upon life-time exposure. The corresponding concentration in soil is derived by dividing the $MPC_{oral,\ bird}$ or $MPC_{oral,\ mammal}$ by an earthworm Biota to Soil Accumulation Factor (BSAF). Derivation of the $SRC_{soil,\ secpois}$ is not described, but for the purpose of this report a similar approach is used in which the NOAEC are divided by the appropriate assessment factor, and the geometric mean of these values is used as the $SRC_{oral,\ bird}$ or $SRC_{oral,\ mammal}$. These values are then divided by the BSAF to obtain the corresponding $SRC_{soil,\ secpois}$.

Recently, a new methodology was developed for derivation of quality standards to protect (predatory) birds and mammals [21]. The method also builds on an energy based approach, although implemented in a different way than previously. In this new method, the bodyweight of a species is used to estimate its daily energy demand under field conditions. The toxicity test result is normalised to the energy content of the particular test food. Using information on energy content of different food types in the field, the exposure of birds and mammals can be estimated for various food webs. The method also addresses the factors that are needed to extrapolate from subacute and semi-chronic exposure to chronic exposure. Furthermore, guidance is given on the use of statistical extrapolation for bird and mammal data. For soil, the major improvement of the method as compared to the standard approach is that a better correction is applied for the low energy content of earthworms as compared to laboratory food. It has been shown that the default factor of 3 used in the European guidance documents [13,15] is an underestimation for earthworms, for which a factor of 5.2 would be needed (see further below). Unfortunately, the necessary information to apply this new method (body weight, daily food intake and energy content of the test food) is not supplied in the mostly older studies on DDT and metabolites. Using assumptions and defaults to generate the necessary input would mean that considerably uncertainty would be introduced. It was therefore decided not to apply the new methodology, but use the standard method instead.

2.2.3.2 Choice of the BSAF for earthworms

As indicated in section 2.3.2 and 2.3.3, different BSAFs for earthworms have been used in the past, i.e. geometric mean and maximum values of 0.27 and 0.51 $kg_{dwt\ soil}/kg_{wwt\ worm}$ for total DDT at 10% OM by Romijn et al. [19,20], default values of 1 and 10 $kg_{dwt\ soil}/kg_{wwt\ worm}$ by Van de Plassche et al. [6], and a geometric mean of 0.17 $kg_{dwt\ soil}/kg_{wwt\ worm}$ by Jongbloed et al. [32,33]. As already indicated in 2.3.2, an overall BSAF of 3.29 $kg_{dwt\ soil}/kg_{wwt\ worm}$ was also reported [19], which is the geometric mean of reliable and less reliable data from laboratory and field studies, without correction for OM content. For the data used by Romijn et al. [19,20] to calculate the OM-corrected BSAF, there seems to be a negative correlation between BSAF and OM content in the laboratory study with freshly contaminated soil, but the BSAF of the other (field)study does not fit into the observed correlation. Moreover, it was shown that accumulation of DDT and DDE decreases with increased ageing times [35,36], indicating that (laboratory) experiments with freshly contaminated soils may not be representative for deriving a BSAF for historically contaminated sites for which the current risk limits apply. Most field studies cited in Romijn et al. are quite old studies that were performed when the use of DDT was still allowed. These studies may also overestimate the accumulation as compared to the current situation.

For the present assessment, earthworm BSAFs were therefore retrieved from studies in which ageing was taken into account. These are studies in which soil and worms were collected from historically contaminated sites, or in which accumulation from historically contaminated field soil was studied in the lab using worms from a breeding culture (or from an uncontaminated site). Romijn et al. [19,20] cited one single reliable field study on DDT [37]. The BSAFs in this study originate from an experimental field plot that had been sampled after ageing for 1, 5 and 11 years after contamination. It appeared that this study was continued, and a recent paper reports on the accumulation after 45 years of ageing [35]. Some other field accumulation studies on DDT were retrieved in addition [36,38-41], from which BSAFs could be calculated. If residues in worms were reported on a dry weight basis, values were converted to wet weight assuming a generic moisture content for earthworms of 84.3% [34,42]. Lipid-based concentrations reported by Hendriks et al. [41] were converted to wet weight based BSAF-values using the reported fat-content in this study. The available BSAF-values in $kg_{dwt\ soil}/kg_{wwt\ worm}$ for DDE and DDT and the sum of all isomers of DDT and metabolites (indicated as sum-DDT) are presented in Table 8 below. If not reported as such, sum-DDT was calculated as the sum of DDE and DDT, multiplying DDE-residues with a factor of 1.1 based on molar mass. The BSAFs are plotted as a function of OM-content in Figure 1.

Table 8 Summary of BSAFs for DDT, DDE and sum-DDT in worms for soils with different organic matter content as reported in the literature. Field = worms sampled from contaminated site, Lab = laboratory exposure of worms to contaminated field soils.

Exposure type	OM [%]	BSAF in $kg_{dwt\ soil}/kg_{wwt\ worm}$ DDT	DDE	sum-DDT	Reference
Field	4		0.84	0.72	[35]
Lab[a]	11.7	0.20	0.27	0.23	[38]
Lab[a]	4.6	0.28	0.62	0.51	[38]
Lab[a]	7.5	0.30	0.43	0.37	[38]
Lab[a]	9.4	0.17	0.29	0.26	[38]
Lab[a]	7.7	0.11	0.31	0.26	[38]
Lab[a]	7.5	0.12	0.38	0.31	[38]
Lab[a]	11.1		0.36		[38]
Lab[a]	7.8	0.24	0.31	0.29	[38]
Field	2.3	0.14	0.52	0.29	[39]
Field	3.3	0.37	0.77	0.59	[39]
Field	3.8	0.29	1.4	0.69	[39]
Field	5	0.46	1.9	0.60	[41]
Field	9	0.070	1.8	0.33	[41]
Lab[b]	4.4	0.45	0.57	0.48	[36]
Lab[b]	5.4	0.47	0.36	0.41	[36]

a: worms from uncontaminated field site
b: worms from breeding culture

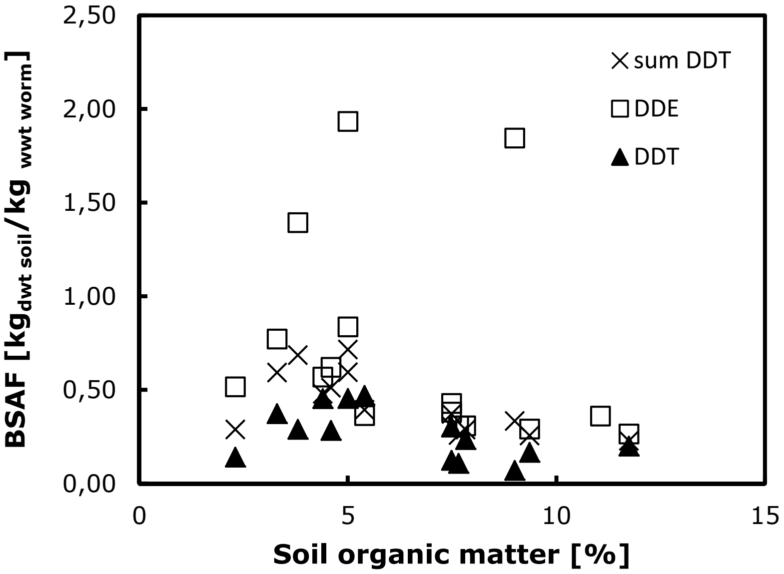


Figure 1 BSAFs for DDT, DDE and sum-DDT in earthworms as a function of organic matter content in soil.

Based on this figure, there is no apparent correlation between soil organic matter content and BSAFs for DDE, due to three relatively high BSAF-values of 1.4 – 1.9 kg$_{dwt\ soil}$/kg$_{wwt\ worm}$. In the original papers, no obvious explanation could be found on the basis of which these studies should be considered as invalid. However, when omitting the data on DDE and plotting the data for DDT and sum-DDT separately on a different scale, there is a clear tendency of decreasing BSAF with increasing OM content (see Figure 2).

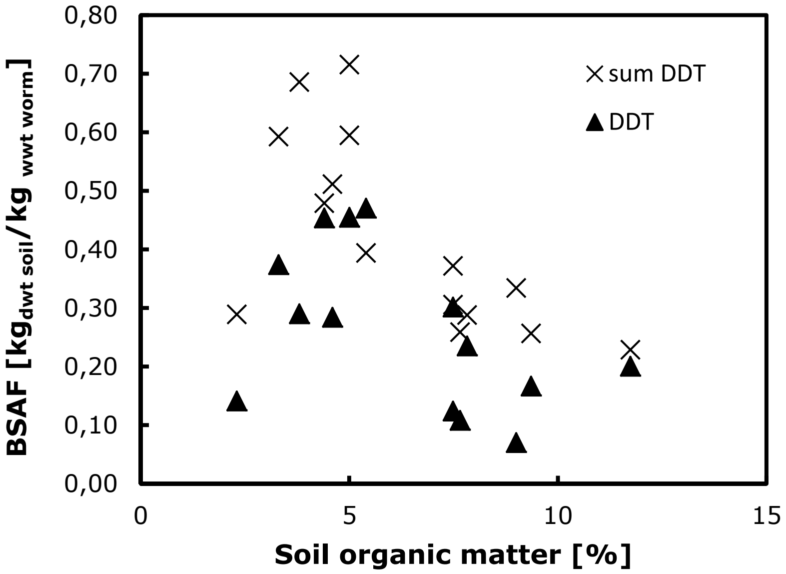


Figure 2 BSAFs for DDT and sum-DDT in earthworms as a function of organic matter content in soil. The same data as used in Figure 1 are plotted using a different scale for the Y-axis.

The correlation is even more obvious when looking at the results of a single experiment. Figure 3 shows the BSAFs for sum-DDT as a function of soil OM based on the data of Gaw et al. [38], who exposed worms from an uncontaminated site to contaminated field soils with different OM content.

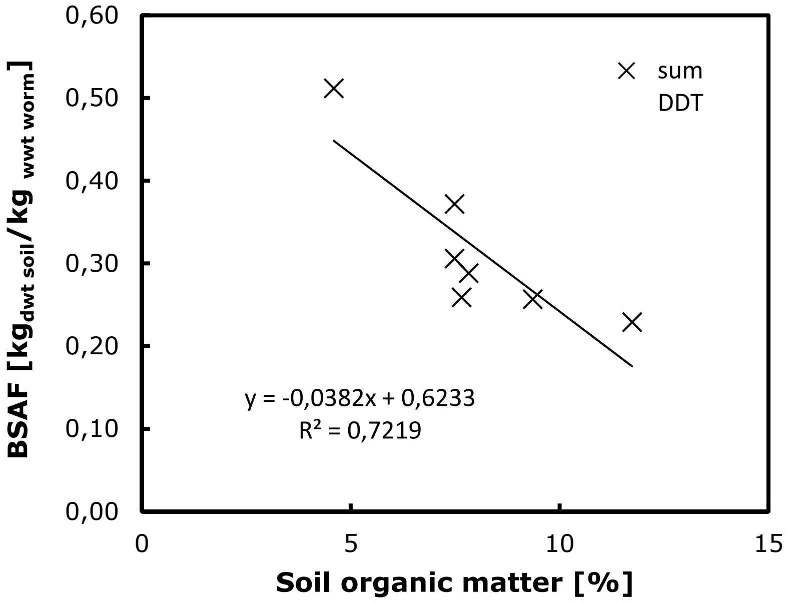


Figure 3 BSAFs for sum-DDT in earthworms as a function of organic matter content in soil. Data from Gaw et al. [38].

Based on this observation and the generally accepted correlation between OM-content and accumulation, it was decided to normalise BSAFs to OM content. Table 9 presents the summary statistics of the original and normalised BSAFs (in $kg_{soil\ OM}/kg_{wwt\ worm}$) for DDT, DDE and sum-DDT. In one of the studies [40], DDE concentrations in soil were reported on a wet weight basis and BSAFs in $kg_{dwt\ soil}/kg_{wwt\ worm}$ could not be calculated. This study is therefore not included in Table 8, but since organic carbon content was reported, OM-normalised BSAFs could be included in the data summarised in Table 9. Theoretically, additional normalisation to lipid content of worms should also be considered. However, actual lipid content was reported in two studies only [40,41]. Using a default lipid content for the other studies would only change the absolute values, but not decrease the relative differences between soils.

Table 9 Summary statistic of BSAFs for DDT and sum-DDT in worms without and with normalisation to soil organic matter content.

	DDT		**DDE**		**sum-DDT**	
	$kg_{dwt\ soil}/kg_{wwt\ worm}$	$kg_{soil\ OM}/kg_{wwt\ worm}$	$kg_{dwt\ soil}/kg_{wwt\ worm}$	$kg_{soil\ OM}/kg_{wwt\ worm}$	$kg_{dwt\ soil}/kg_{wwt\ worm}$	$kg_{soil\ OM}/kg_{wwt\ worm}$
# values	14	14	15	17#	14	14
minimum	0.07	0.003	0.27	0.012	0.23	0.007
maximum	0.47	0.025	1.93	0.170	0.72	0.030
geomean	0.23	0.013	0.56	0.039	0.39	0.022
mean	0.26	0.015	0.70	0.055	0.42	0.023
SD[a]	0.14	0.007	0.55	0.053	0.16	0.006
CV[b]	52%	47%	78%	96%	39%	25%

a: standard deviation
b: coefficient of variation
#: data from Hebert et al. [40] could only be used to calculate OM-normalised BSAFs

Based on this analysis, the OM-normalised BSAFs for sum-DDT represent the most robust estimate of DDT-accumulation in worms. The geometric mean BSAF of 0.022 $kg_{soil\ OM}/kg_{wwt\ worm}$ is used for further calculations.

2.2.3.3 Risks for worm-eating birds

The available data from the 1991-report are presented in Appendix 2, together with additional data from an update in 1994 [32]. In some cases, the lowest dose tested gave a significant effect. In case the effect was 20% or less, the NOEC was derived dividing the Lowest Observed Effect Concentration (LOEC) by a factor of 2. A factor of 3 was used if 20-50% effect occurred. According to present guidance [14,17], deriving a NOEC from a LOEC with <20% effect is still allowed, but the extrapolation from higher effect percentages is no longer used and these LOEC-data can only be used as supporting information.

The US EPA Ecotox database and the previously mentioned Eco-SSL report [23,24] were consulted to confirm the available data, and to check for additional data on reproduction and growth of birds. Mortality data were not taken into account, since this is not the most sensitive endpoint for toxicity of DDT and metabolites to birds. All potentially relevant studies in the Ecotox database were also included in the Eco-SSL report, and the data from the latter were further explored. Relevant No Observed Adverse Effect Concentrations (NOAEC in mg/kg_{fd}) and No Observed Adverse Effect Levels (NOAEL in mg/kg_{bw} per day) are listed in Appendix 2, Table A2.2. Note that almost all data used previously by RIVM are also included in the Eco-SSL dataset.

From the available data, the lowest value per species for either DDT, DDD or DDE was selected. No molar conversion was applied to express all data on the basis of DDT, because there is no obvious difference in toxicity. Moreover, in some tests a mixture was applied, while for the others it can be assumed that although the test substance was DDT, exposure to metabolites will have occurred due to conversion in the food or in the organisms. Another point is that molar conversion will only have a minor effect.
It appears from Appendix 2 that large differences exist in test results for species for which many studies are available, such as the mallard duck

Anas platyrhynchos, the japanese quail *Coturnix japonica* and the chicken *Gallus domesticus*. For these species, the lowest and highest NOAEL and NOAEC-values may differ an order of magnitude or more. The lowest test results were confirmed by checking the underlying study or its abstract. For example, for the chicken, the lowest test result is a 10-weeks LOEC of 0.1 mg/kg$_{fd}$ for reproduction, based on a significant reduction in the number of chicks per hen by 18, 34 and 38% at 0.1, 1 and 10 mg/kg$_{fd}$, respectively [43]. In another study with the same duration, no effects on eggshell quality, egg production or hatchability were observed at 100 mg/kg$_{fd}$ (abstract checked) [44]. It is not clear what is the cause for the different results in these studies. One possibility is the use of different DDT analogues and/or different bird breeds. In previous assessments, the geometric mean was taken if for a species multiple test results were available. At present, taking the geometric mean is in general only done for (standard) tests which are performed in a similar way. This is not the case here, and the lowest test result is used for further calculations.

Table 10 lists the resulting NOAEC-data for birds. If for a species only a LOAEL or LOAEC was available and the effect level was <20%, the result is presented as "< LOAEC/2" or "LOAEC/2". If the effect level could not be checked because the reference (or abstract) was unavailable, the result is given as a <-value.

In the evaluation of 1991 and 1994, an assessment factor of 10 was applied to extrapolate the results from short-term tests to longer durations. According to the current guidance, short-term LC50-values may be used with an assessment factor of 3000, but preference is given to chronic NOEC-values, to which an assessment factor of 30 is applied. The test duration of a chronic reproduction study according to OECD guidelines is at least 20 weeks. The present dataset also contains bird studies that can be considered as short-term (5 d NOEC for *Columba livia*) or semi-chronic, i.e. lasting 5 - 15 weeks. The guidance does not propose assessment factors for these non-standard studies, but since sub-lethal effects are measured, the factor of 30 is considered appropriate when reproductive parameters have been measured. When the only data for a species refer to body weight (*Pelecanus erythrorhynchos* and *Phalacrocorax auritus*) or histopathology without measuring actual reproduction (*Meleagris gallopavo*), a factor of 30 would possibly not be protective, but the higher factor of 3000 is not appropriate either. Choosing a factor in between would mean a rather arbitrary choice. Therefore, the NOAEC-values are used with an assessment factor of 30 to derive an MPC$_{oral,\ bird}$ per species.

Table 10 Lowest NOAEC-values per species for DDT and metabolites from long-term tests with birds and $MPC_{oral, bird}$ values derived using the default assessment factor of 30.

Species	Exposure time	Endpoint	Tested as	NOAEC [mg/kg_{fd}]	$MPC_{oral, bird}$ AF 30 [mg/kg_{fd}]
Anas platyrhynchos	22 w	egg shell thinning	DDE	1	0.033
Anas rubripes	8 m	egg shell thinning	DDE	< 5	< 0.17
Colinus virginianus	8 m	body weight	DDT	≥ 25	≥ 0.83
Columba livia	5 d	testes degeneration	DDD	< 3	< 0.10
Coturnix japonica	5 w	progeny counts	DDT	5	0.17
Falco sparverius	6 m	egg shell thinning	DDE	0.3	0.010
Gallus domesticus	10 w	reproduction	DDT	0.05	0.0017
Haliaeetus leucocephalus	55 d	body weight	DDT	< 10	< 0.33
Lonchura striata	6 w	progeny counts	DDT	< 9	< 0.30
Meleagris gallopavo	15 w	reproductive histology	DDT	265	8.8
Otus asio	20 m	egg shell thinning	DDE	2.8	0.09
Pelecanus erythrorhynchos	10 w	body weight	sum	72	2.4
Phalacrocorax auritus	9 w	body weight	sum	25	0.83
Phasianus colchicus	11 w	egg shell thinning	DDE	10	0.33
Streptopelia risoria	90 d	reproduction	DDE	5	0.17
Tyto alba	1 y	progeny counts	DDE	< 1.5	< 0.050
Zonotrichia albicollis	6 w	body weight	DDT	< 5	< 0.17

The lowest $MPC_{oral, bird, AF}$ is then 0.0017 mg/kg_{fd}, while based on the geometric mean of the unbound values, the $SRC_{oral, bird AF}$ is 0.16 mg/kg_{fd}.
Taking the $MPC_{oral, bird}$ of 0.0017 mg/kg_{fd} and the BSAF of 0.022 $kg_{soil OM}/kg_{wwt worm}$ (see section 2.2.3.2), the $MPC_{soil, secpois, bird, AF}$ is 77 $\mu g/kg_{soil OM}$. The $SRC_{soil, secpois, bird, AF}$ is 730 $\mu g/kg_{soil OM}$ (rounded values). Expressed on the basis of Dutch standard soil with 10% OM, these values are equivalent to 8.0 and 70 $\mu g/kg_{dwt soil}$, respectively (rounded values).

Because more than eight species are available, it is reasonable to use statistical extrapolation. For this, the program MOSAIC-SSD was used, which is able to fit SSDs based on datasets with censored data [45]. If SSDs are applied, the original assessment factor of 30 may be lowered. According to the new method [21], when a full correction for caloric content is made, the default correction factor of 3 for the difference in caloric content between laboratory food and field prey can be omitted and a factor of 10 would be put on the lowest NOEC instead of default factors of the TGD and REACH guidance [13,14,17]. For the derivation of an SSD-based MPC, a default assessment factor of 5 is put on the HC5. Depending on the size and quality of the dataset, stepwise lowering of this factor may be considered. For the SRC, the geometric mean of the NOAECs is taken, and the HC50 is used with an assessment factor of 1. In this case, however, because a full correction for caloric content cannot be made, the above mentioned default factor of 3 should still be applied, i.e. the SSD should be run using the NOAEC-values of Table 10 with an assessment factor of 3.

When doing so using a log-normal distribution, the HC5 (with 95% confidence limits) is estimated as 12.2 µg/kg$_{fd}$ (95% CL 1.6-128) and the HC50 as 824 µg/kg$_{fd}$ (95% CL 204-3104). Using a log-logistic distribution results in similar values. With 17 values the dataset is reasonably large and covers potentially sensitive endpoints. On the other hand, about half of the data are unbound values, which introduces additional uncertainty. Therefore, putting an assessment factor of 3 on the HC5 is considered justified for derivation of the MPC$_{soil, secpois}$. This results in an MPC$_{oral, bird, SSD}$ of 4.1 µg/kg$_{fd}$.
Using this MPC$_{oral, bird, SSD}$ and the BSAF of 0.022 kg$_{soil\ OM}$/kg$_{wwt\ worm}$ (see 2.2.3.2) the MPC$_{soil, secpois, bird, SSD}$ is 190 µg/kg$_{soil\ OM}$. The SRC$_{soil, secpois, bird\ SSD}$ is 0.824 / 0.022 = 37.5 mg/ kg$_{soil\ OM}$. These values are equivalent to **20** and **3800 µg/kg$_{dwt\ soil}$,** respectively, for Dutch standard soil (rounded values). The MPC$_{soil, secpois, bird, SSD}$ and SRC$_{soil, secpois, bird\ SSD}$ should be interpreted as risk limits for the sum of DDT and metabolites.

Note that the SRC-values are most likely too high and give an underestimation of the risk, because is it not sure if the assessment factors are high enough to cover uncertainties with respect to study duration and endpoints considered and with respect to the extrapolation from laboratory food to field prey. Furthermore, the SRC does not cover biomagnification to higher organisms. This is further discussed in section 2.2.3.5.

2.2.3.4 Risks for worm-eating mammals

Similar to what is described above, the available data for mammals from the 1991-report and update from the 1994-report [32] are presented in Appendix 3, table A3.1. The previously mentioned Eco-SSL report [24] was consulted to check for additional data on reproduction and growth of mammals. Mortality data were not taken into account, since the evaluation by the US EPA shows that this is not the most sensitive endpoint [24]. Relevant No Observed Adverse Effect Concentrations (NOAEC in mg/kg$_{fd}$) and No Observed Adverse Effect Levels (NOAEL in mg/kg$_{bw}$.d) are listed in Appendix 3, Table A3.2. Note that not all data used previously by RIVM are included in the Eco-SSL dataset.

From the available data, the lowest value per species for either DDT, DDD or DDE was selected (see Table 11). In case only a NOAEL was available, the NOAEC expressed as dietary concentration was estimated using (default) values on food intake and body weight. The lowest available NOAEC for the rat from a dietary study is 1 mg/kg$_{fd}$ for reduced ovary weight (reference checked) [46]. However, a 120-days LOAEL of 0.2 mg/kg$_{bw}$.d was obtained based on 30% reduction in body weight gain [47], which is equivalent to a NOAEC of < 1 mg/kg$_{fd}$.

A 10-fold lower LOAEL of 0.02 mg/kg$_{bw}$.d could not be verified because the abstract could not be retrieved. The data for rhesus monkeys (*Macaca mulatta*) reported by Jongbloed et al. [32] were not included in the Eco-SSL report. The LOAEL of 5 mg/kg$_{bw}$.d for the squirrel monkey *Salmura sclureus* [48] was verified from the study abstract, but because only mortality was assessed in this study the result is not included here. The results for the rhesus monkey could be verified: absence of mortality and clinical signs at 200 mg/kg$_{fd}$ (equivalent to 6.6 mg/kg$_{bw}$.d), but reproduction was not assessed in this study [49]. Considering the duration of the tests, an assessment factor of 30 should be used according to the current guidance [13,14,17].

Table 11 Lowest NOAEC-values per species for DDT and metabolites from long-term tests with mammals and MPC$_{oral,\ mammal}$ values derived using the default assessment factor of 30.

Species	Exposure time	Endpoint	Tested as	NOAEC [mg/kg$_{fd}$]	MPC$_{oral,\ mammal}$ AF 30 [mg/kg$_{fd}$]
Canis familiaris	3 gen	age at puberty	DDT	11	0.37
Macaca mulatta	7.5 y	clinical signs	DDT	200	6.7
Mesocricetus auratus	72 w	body weight	DDE	500	17
Mus musculus	120 d	fertility	DDT	< 7	< 0.23
Oryctolagus cuniculus	116 d	progeny counts	DDT	25$^{\#}$	0.83
Ovis aries	9 m	progeny counts	DDT	10	0.33
Peromyscus polionotus	15 m	progeny counts	DDT	18$^{\#}$	0.60
Rattus norvegicus	120 d	body weight	DDT	< 1$^{\#}$	< 0.033

recalculated from dietary dose using information in Eco-SSL report [24].

In view of the fact that the lowest values of the dataset are <-values, it is considered not appropriate to only use the next higher bound values for risk limit derivation. Therefore, the program MOSAIC-SSD was used. In accordance with the procedure for birds, a log-normal distribution was fit to the NOAEC-values from Table 12, using an assessment factor of 3 instead of 30.

The HC5 is estimated as 126 µg/kg$_{fd}$ (95% CL 16.1 - 1566) and the HC50 as 4549 µg/kg$_{fd}$ (95% CL 962 - 22087). Assuming a log-logistic distribution results in similar values. In this case, because the number of datapoints is low and the spread around the HC-estimates is large, the highest assessment factor of 5 is used for derivation of the MPC$_{soil,\ secpois}$. This results in an MPC$_{oral,\ mammal,\ SSD}$ of 25.2 µg/kg$_{fd}$. Using the BSAF of 0.022 kg$_{soil\ OM}$/kg$_{wwt\ worm}$ (see 2.3.4.2) the MPC$_{soil,\ secpois,\ mammal,\ SSD}$ is 1150 µg/kg$_{soil\ OM}$. The SRC$_{soil,\ secpois,\ bird\ SSD}$ is 4.5 / 0.022 = 205 mg/kg$_{soil\ OM}$. Expressed on the basis of Dutch standard soil with 10% OM, this is equivalent to **120** and **21000 µg/kg$_{dwt\ soil}$**, respectively (rounded values).

The MPC$_{soil,\ secpois,\ mammal,\ SSD}$ and SRC$_{soil,\ secpois,\ mammal\ SSD}$ should be interpreted as risk limits for the sum of DDT and metabolites.

As for birds, there is uncertainty if the default assessment factors are high enough to cover uncertainties and the SRC does not cover biomagnification to higher organisms. The next section addresses this issue.

2.2.3.5 Risks for higher predators

The present assessment is based on worm eating birds and mammals. Apart from the uncertainty associated with the default assessment factors, a major point is that the exposure of higher predators is not taken into account. In the absence of adequate data, it is not possible to overcome this problem by applying the new method. However, even without a quantitative assessment some data can be presented to further underpin the importance of biomagnification and exposure of higher predators.

In a field study on organochlorine transfer in a terrestrial foodweb, residues of DDT, DDE and DDD were measured in soil, earthworms, mammals and eggs of different bird species birds sampled over the years 1987-1989 on different locations in Ontario, Canada [40]. A further food chain study was conducted in 1989 at two locations with high and low DDE-levels. Residues of DDE in soil, worms (*Lumbricus* sp.), red clover (*Trifolium pratense*), alfalfa (*Medicago sativa*), timothy (*Phleum pratense*), brome grass (*Bromus* sp.), meadow vole (*Microtus pennsylvanicus*) and white-footed mouse (*Peromysccus leucopus*) and eggs of starling (Sturnus vulgaris), American robin (*Turdus migratorius*) and American kestrel (*Falco sparverius*). Results are summarised in the following table.

Table 12 Concentrations of DDE in soil, earthworms, mammals and eggs of different bird species sampled on two locations in Southern Ontario in 1989. N = number of samples included in pooled sample, for mammals N = individual whole body analyses on which mean is based. OC = organic carbon, ND = not detectable. Data copied from Hebert et al. [40].

Sample	Grimsby			St. Thomas		
	N	DDE [mg/kg$_{wwt}$]	% OC/ % lipid	N	DDE [mg/kg$_{wwt}$]	% OC/ % lipid
Soil	10	0.343	5.83	9	0.004	5.01
Plants[a]	40	0.009 ± 0.003		36	ND	
Worm	10	0.605	1.4	10	0.007	1.2
Mouse	7[b]	0.002 ± 0.004	2.68 ± 1.06	8	0.003 ± 0.007	2.22 ± 0.27
Vole	11[b]	0.016 ± 0.021	2.14 ± 0.54	12	0.015 ± 0.014	2.49 ± 0.87
Starling[c]	11	8.812	6.31	10	0.530	5.94
Robin[c]	9	17.250	5.48	8	1.247	5.37
Kestrel[c]	10	5.535	6.22	9	0.117	6.16

a: mean of four plant species
b: number of individual whole body analyses
c: values refer to eggs

Using the mean values in Table 12, biota and egg to soil accumulation factors (BSAFs and ESAFs) for Grimsby soil are calculated by dividing the biota or egg wet weight concentration by the concentration in soil.

The same is done for the lipid normalised concentrations. Results are presented in Table 13. Note that the organic carbon content of the soil (5.83%) is equal to that of Dutch standard soil. As an indication of the biomagnification through the food chain, the BSAF for mammals and ESAF for bird eggs is divided by the BSAF for worms.

Table 13 Biota to Soil Accumulation Factors (BSAF) for DDE in worms and mammals and Egg to Soil Accumulation Factors for DDE in birds (ESAF), expressed on the basis of wet weight [$kg_{wwt\ soil}/kg_{wwt\ biota\ or\ egg}$] or on the basis of lipid content [$kg_{wwt\ soil}/kg_{wwt\ lipid}$]. Values are calculated using the data in Table 12. The ratio of the BSAF for mammals or bird eggs relative to worms is given. Values are calculated using data reported in Hebert et al. [40].

Sample	BSAF or ESAF [$kg_{wwt\ soil}/kg_{wwt\ biota\ or\ egg}$]	relative to worm	BSAF or ESAF [$kg_{wwt\ soil}/kg_{wwt\ lipid}$]	relative to worm
Grimsby			126	
Worm	1.76			
Mouse	0.006	0.003	0.22	0.002
Vole	0.047	0.03	2.18	0.02
Starling	25.7	14.6	407	3.23
Robin	50.3	28.56	918	7.28
Kestrel	16.1	9.15	259	2.06
St. Thomas				
Worm	1.75		300	
Mouse	0.75	0.43	555	1.85
Vole	3.75	2.14	623	2.08
Starling	133	75.7	1485	4.95
Robin	312	178	1343	4.48
Kestrel	29.3	16.7	1540	5.13

For St. Thomas, absolute BSAF-values are much higher than for Grimsby, but it can be assumed that the uncertainty in the data is also much higher because of the relatively low concentrations of DDE in soil. When considering accumulation in bird eggs, the difference with the worms is in the same range as at Grimsby.
It can be seen that in the Grimsby samples, the wet weight based accumulation of DDE in bird eggs relative to soil (ESAF) is 9 to 29 times higher than in earthworms. Normalised to lipid content, the difference between bird eggs and worms is a factor of 2 to 7. For the present assessment, this means that derivation of the $MPC_{soil,\ secpois}$ and $SRC_{soil,\ secpois}$ using a BSAF for earthworms may underestimate the intake of DDE by predators feeding on bird eggs.

Differences between species can partly be explained from difference in lipid content, since correction for lipid content decreases the differences between species. According to the authors, diet composition is another important factor explaining the differences in accumulation levels between species. The robin is a typical worm-eater, while the starling feeds mainly on insects. Kestrels feed on grasshoppers and small mammals. The small mammals in this study are mainly feeding on plants, which can explain the absence of accumulation relative to worms. Residues of DDE in plants were relatively low (see Table 12) which is reflected in relatively low DDE residues in kestrel eggs. The authors report that the levels found in earthworms are lower than those associated with adverse effects on robins in another study. However, hatching success of kestrels in this study at the Grimsby site was about 50% lower than at St. Thomas and fledging success was 25% lower. The number of young produced was also reduced.

In another study by Harris et al. [39], accumulation of DDT, DDE and DDD in earthworms and American robin was determined in soil, earthworms and birds (eggs and nestlings) in Canadian orchards that had been treated with DDT in the past. Orchards were located in the same region as the above described study, a non DDT-treated orchard was included as reference site. Samplings were undertaken during 1993-1995. A summary of measured concentrations from the DDT-treated orchards is given in Table 14.

Table 14 Summary of measured concentrations of DDE and DDT in soil, earthworms and American robin in DDT-treated orchards in the Niagara (Nia), Simcoe (Sim) and Okanagan (Oka) region in Northern Canada. Data taken from [39].

Sample	DDE			DDT			sum-DDT[a]		
	Nia	Sim	Oka	Nia	Sim	Oka	Nia	Sim	Oka
Soil									
OM (%)[b]	2.3	3.3	3.8	2.3	3.3	3.8	2.3	3.3	3.8
mg/kg$_{\text{dwt}}$	0.79	3.6	4.9	1.0	3.4	9.3	1.9	7.1	14.4
Worm[c]									
mg/kg$_{\text{dwt}}$	2.6	17.7	43.5	0.90	8.1	17.2	3.5	26.8	62.9
mg/kg$_{\text{wwt}}$[d]	0.41	2.8	6.8	0.14	1.3	2.7	0.55	4.2	9.9
Robin egg									
mg/kg$_{\text{dwt}}$[e]	177	258	486	23	55	74.3	219	345	616
mg/kg$_{\text{wwt}}$	30.7	44.6	85.1[f]	3.9	9.6	13.0 [e]	37.8	59.8	108
Robin nestling									
mg/kg$_{\text{dwt}}$[e]	41.7	84.9	-	0.7	2.8	-	47.9	103	-
mg/kg$_{\text{wwt}}$	9.9	19.7	-	0.2	0.2	-	11.4	23.9	-

a: if not reported by the authors, sum-DDT was calculated as the sum of DDE, DDD and DDT with correction for molar mass
b: 0-10 cm
c: average values for all species from Table 2 in [39]
d: calculated based on default moisture content of 84.3% [34,42]
e: calculated based on reported moisture
f: average values taken from Table 3 in [39]

It would be expected that concentrations in worms would increase with decreasing organic matter content, but this is not the case here. From the concentrations reported in Table 14, BSAFs and ESAFs can be calculated that are presented in Table 15 (note that earthworm BSAFs are also included in Table 8). This table also gives the biomagnification factor (BMF) from worms to eggs and birds, calculated as the ratio of residues in eggs/nestlings and worms, both on wet weight basis and corrected for lipid content. For this, reported lipid content in eggs (5.2-5.9%) and nestlings (2.9 – 3.7%) was used together with an assumed lipid content in earthworms of 1%.

Table 15 Biota to Soil Accumulation Factors (BSAF) in worms and nestlings and Egg to Soil Accumulation Factors (ESAF) for DDE, DDT and sum-DDT. All values are based on wet weight organism concentrations and dry weight soil concentrations as presented in Table 14. The biomagnification factor (BMF) represents the accumulation in eggs and nestlings relative to worms.

	DDE			DDT			sum-DDT		
	Nia	Sim	Oka	Nia	Sim	Oka	Nia	Sim	Oka
BSAF/ESAF[a]									
worm	0.52	0.77	1.4	0.14	0.37	0.29	0.29	0.59	0.69
egg	39	12	17	3.9	2.8	1.4	20	8.4	7.5
nestling	13	5.5		0.17	0.047		6.0	3.4	
BMF									
worm to egg (wwt)	75	16	12	28	7.5	4.8	69	14	11
worm to egg (lipid)	14	3.1	2.1	5.3	1.5	0.82	13	2.7	1.9
worm to nestling (wwt)	24	7.1		1.2	0.1		21	5.7	
worm to nestling (lipid)	8.4	2.2		0.41	0.086		7.2	4.4	

a: expressed in kg$_{\text{dwt soil}}$/kg$_{\text{wwt biota}}$

Wet-weight based ESAFs for DDE range from 12 to 39 kg$_{\text{dwt soil}}$/kg$_{\text{wwt egg}}$. These ESAFs are consistent with the data for Grimsby presented above in Table 13 (ESAF 16.1-50.3 kg$_{\text{wwt soil}}$/kg$_{\text{wwt egg}}$). Note that the latter are presented on the basis of wet weight soil, corresponding values for dry weight soil would be lower. For nestlings, the BSAFs for DDE are 5.5 and 13 kg$_{\text{dwt soil}}$/kg$_{\text{wwt bird}}$. Corresponding values for DDT are about a factor of 10 lower, while values for sum-DDT are about half those for DDE.

The authors of this paper also report bioaccumulation factors from earthworms to robins, and give ranges of 6 to 145 for eggs and 0.04 to 73 for nestlings. However, our calculations give different results (see Table 15) and the author's figures could not be deduced from the reported residue data. For example, the value of 145 refers to an egg from the Okanagan region containing 17.8 mg DDT/kg$_{\text{wwt}}$, which is equivalent with 86.4 mg/kg$_{\text{dwt}}$ given the moisture content of 79.4%. The reported overall average concentration of DDT in all earthworms species from that site is 17.2 ± 6.1 mg/kg$_{\text{dwt}}$, averages for individual species are between 13.8 and 30.3 mg/kg$_{\text{dwt}}$. The maximum ratio between concentrations in these eggs and worms from this site is thus a factor of 3.

According to our calculations (Table 15), the maximum ratio between DDE accumulation in eggs and worms is 75 for Niagara. For nestlings, DDE accumulation differs by a factor of 7 to 24. After correction for lipid content, the difference in DDE accumulation between birds and worms is a factor of 2 to 14 for eggs, and a factor of 2 to 8 for nestlings. This is in agreement with the data for Grimsby, where lipid corrected accumulation of DDE in birds eggs was 2 to 7 times higher than in worms (see Table 13).

In a third study, the accumulation of metals and organochlorine compounds in soils, earthworms and shrews was measured at two locations in floodplains of the River Rhine in 1993 [41]. Reported concentrations in soil, earthworms and shrew liver are summarised in

Table 16. Concentrations in worms and shrew liver were recalculated from fat-based values to wet weight using reported fat contents.

Table 16 Concentrations in soil, earthworms and shrew liver samples at two locations in floodplains of the River Rhine [41]. Values for worms and shrew liver were recalculated from reported fat-based values.

	Ochten (5% OM)				Gelderse Poort (9% OM)			
	DDT	DDD	DDE	sum-DDT	DDT	DDD	DDE	sum-DDT
Soil [μg/kg$_{dwt}$]	6.8	4.3	3.2	15	14	34	22	92
Worm[a] [μg/kg$_{wwt}$]	3.1	4.9	6.2	8.9	0.98		31	
Shrew liver[b] [μg/kg$_{wwt}$]			47	47			20	20

a: recalculated using reported fat content of 1.2%

b: recalculated using reported fat content in liver of 3.36% (Ochten) and 2.98% (Gelderse Poort)

From the data it is clear that for location Ochten, the sum-DDT concentration in worms is likely underestimated, because it is much less than the summed concentrations of DDT, DDD and DDE. At Ochten, accumulation in shrew livers is higher than in earthworms, the wet weight based BSAF for DDE is 14.7 kg$_{dwt\ soil}$/kg$_{wwt\ liver}$. For Gelderse Poort, the BSAF for DDE in shrew liver is 1.7 kg$_{dwt\ soil}$/kg$_{wwt\ liver}$, which is comparable to that of worms. Corresponding values for sum-DDT are 3.1 and 0.22 kg$_{dwt\ soil}$/kg$_{wwt\ liver}$ for Ochten and Gelderse Poort, respectively.

Conclusion

Based on the data presented above, it is concluded that the accumulation of DDE relative to soil is higher in bird eggs, nestlings and shrew livers as compared to earthworms. The accumulation factors from birds/eggs to soil for DDE are between 5.5 and 39 kg$_{dwt\ soil}$/kg$_{wwt\ bird(egg)}$, this is a factor of 7 to 75 higher than in worms from the same sites. To protect higher predators feeding on birds and eggs, an additional factor should be put on the MPC$_{soil,secpois}$ and SRC$_{soil,\ secpois}$ for worm-eating birds. Considering the fact that lipid content in eggs is about a factor of 5 higher than in worms, using a additional biomagnification factor of 10 is considered appropriate.

2.3 Summary and conclusions on DDT and metabolites

It is concluded that new data on direct ecotoxicity of DDT will not lead to better underpinned ecological risk limits for soil. The aquatic dataset can be improved, but equilibrium partitioning will most likely result in similar risk limits as derived before. Secondary poisoning is taken into account for derivation of risk limits for DDT and metabolites, because this can be more critical and is a relevant factor in soil management.

The MPC$_{soil,\ secpois}$ based on secondary poisoning of DDT and metabolites in worm-eating mammals is 120 μg/kg$_{dwt\ soil}$ in Dutch standard soil. This is about a factor of 10 higher than the previously set value for direct ecotoxicity of DDT. The SSD-based SRC$_{soil,\ secpois}$ for worm-eating mammals of 21000 μg/kg$_{dwt\ soil}$ is also much higher than the previously used value. It was concluded previously that birds are more sensitive to

DDT than mammals [6,20], this is confirmed by the present calculations. The risk limits for soil should therefore be based on birds.

Taking the SSD-based results, the **MPCsoil, secpois** for worm-eating birds is **20 µg/kgdwt soil** in Dutch standard soil with 10% OM. This value refers to the sum of DDT and its metabolites. The previously derived $MPC_{soil, eco}$ for DDT is 0.01 $mg/kg_{dwt soil}$ (10 $µg/kg_{dwt soil}$). The value including secondary poisoning is about a factor of two higher. The newly derived $SRC_{soil, secpois}$ for worm-eating birds is **3800** $\mathbf{µg/kg_{dwt soil}}$ in Dutch standard soil. This is almost a factor of four higher than the previously derived value of 1 $mg/kg_{dwt soil}$ (1000 $µg/kg_{dwt soil}$) based on direct ecotoxicity of DDT.

The above presented values for worm-eating birds are based on a simple food chain and do not account for biomagnification through the food chain. Therefore, the values are underprotective for higher predators. Based on field data on accumulation of DDT and metabolites in terrestrial food chains, it is reasonable to use an additional factor of 10 to protect higher predatory birds feeding on small birds, eggs or small mammals. This would result in an SSD-based **MPCsoil, secpois of 2.0 µg/kgdwt soil** and $\mathbf{SRC_{soil, secpois}}$ **of 380** $\mathbf{µg/kg_{dwt soil}}$ for the sum of DDT and its metabolites (rounded values). These values are lower than the current ones.

The derived $MPC_{soil, secpois}$ and $SRC_{soil, secpois}$ for worm-eating birds and higher predatory birds are presented in Table 17 together with current values based on direct ecotoxicity. Corresponding intermediate ecological values used in soil management are calculated as the geometric mean of MPC and SRC. Current background values for DDT and related compounds are set to 200, 100 and 20 $µg/kg_{dwt soil}$ for DDT, DDE and DDD, respectively. These values refer to standard soil with 10% OM and are based on the 95th percentile in the upper 10 cm soil layer of unsuspected areas [50,51]. The current $MPC_{soil, eco}$ for DDT and DDE are lower than the background value, the value for DDD is only slightly higher. The $MPC_{soil, secpois}$ for worm-eating birds derived here for the sum of DDT and metabolites is also lower than the sum of the background values, and this is even more so when predatory birds are considered. This indicates that any level above the background value in the top soil is undesirable. The $MPC_{soil, secpois}$ value could be reason to lower the current values for the re-use of excavated soils, especially when it comes to green areas. Environmental gains are achieved by the removal of soil with higher levels of DDT and metabolites.

Table 17 Summary of derived risk limits for the sum of DDT and related compounds based on secondary poisoning of worm-eating birds and higher predatory birds. All values in μg/kg$_{dwt\ soil}$ for Dutch standard soil with 10% organic matter. Current risk limits based on direct ecotoxicity are presented as well, based on [1,51].

Risk limit based on	MPC$_{soil}$	SRC$_{soil}$	Intermediate ecological value
worm-eating birds	20	3800	280
higher predatory birds	2.0	380	28
current values based on direct ecotoxicity[a]			
DDT	10	1000	200 (sum DDT)[b]
DDE	13	1300	130 (sum DDE)
DDD	21	34000	845 (sum DDD)

a: MPC and SRC-values from [1], intermediate ecological values from [51].
b: This value is by policy decission based on the background value of relatively undisturbed soils in the Netherlands.

3 Dieldrin, aldrin and endrin

3.1 Direct ecotoxicity

For dieldrin, the data on direct ecotoxicity for soil organisms used in 2001 [1] originate from a report by Van de Meent et al [5]. Data involved acute tests on terrestrial species and soil processes and one chronic NOEC for insects. From the original report, it appears that this NOEC was calculated from the lowest concentration that didn't cause mortality after 24 hours. For aldrin, the data from the 1994-report of Van de Plassche [6,22] were used. The chronic data on bacteria in this report likely originate from tests with agar plates, while the NOECs for fungi are extrapolated from tests in which >30% effect was observed. This means that a true NOEC is not available. Acute data were present for earthworms, nematodes and springtails, but the latter group was tested in sand with <1% OM. For endrin, only one acute value for springtails was available in 2001, this also concerned a test in sand. The $SRC_{soil, eco}$ for the combination of dieldrin and aldrin was set to 0.22 $mg/kg_{dwt soil}$ based on the geometric mean of the combined acute terrestrial ecotoxicity data (expressed as dieldrin) with an assessment factor of 10, because this result was lower than the geometric mean of the available NOECs (19 $mg/kg_{dwt soil}$). The $SRC_{soil, eco}$ for endrin was set to 0.095 $mg/kg_{dwt soil}$, based on the single acute value with an assessment factor of 10. The $MPC_{soil, eco}$-values for aldrin and endrin were based on equilibrium partitioning, using the combined aquatic data for both compounds with their respective soil partitioning coefficients. Resulting MPC_{soil}-values were 0.043 and 0.038 $mg/kg_{dwt soil}$, for aldrin and dieldrin, respectively. The $MPC_{soil, eco}$ for endrin was set to 0.00095 $mg/kg_{dwt soil}$, based on the acute result with an assessment factor of 1000.

In 2002, an additional literature search was carried out, which resulted in some potentially relevant references for drins [16]. References were not further evaluated at that time, but a quick scan of the abstracts reveals that all references concern acute studies. Based on an extensive literature review reported in 2007, the US EPA concluded that it was not possible to derive risk limits for dieldrin based on direct ecotoxicity to invertebrates and plants [52], and the American soil screening levels were based on secondary poisoning. Regarding equilibrium partitioning, it is noted that the previously used aquatic dataset consisted mainly of acute data, only few of which were based on measured concentrations. Based on a screening of the US EPA Ecotox database [23], it is expected that little or no additional aquatic data can be retrieved. It is concluded that the risk limit for direct toxicity cannot be improved. For the purpose of this report, the additional evaluation for drins is therefore focused on secondary poisoning.

3.2 Assessment of secondary poisoning

3.2.1 *Previous assessment: risks for worm eating birds and mammals*

Similar to DDT and metabolites (see section 2.2.2), secondary poisoning of birds and mammals by dieldrin was evaluated in 1991 by Romijn et al. [20]. It was concluded that secondary poisoning was less critical as compared to direct ecotoxicity (see Table 5). Calculations were based on a BSAF of 0.33 $kg_{dwt\ soil}/kg_{wwt\ worm}$, valid for standard soil with an OM-content of 10%. The uncorrected geometric mean BSAF from laboratory and field tests is 2.17 $kg_{dwt\ soil}/kg_{wwt\ worm}$ [19]. This latter value was also used in [16], but refers to a dataset with laboratory data and quite old less reliable field studies. Another assessment for dieldrin, aldrin and endrin was made in 1994 by Van de Plassche [6], who used data for birds and mammals alone or in combination with data on direct ecotoxicity. Default BSAFs of 1 and 10 $kg_{dwt\ soil}/kg_{wwt\ worm}$ were used. Bird and mammal toxicity data for aldrin and endrin can be found in the annex to that report [22], data for dieldrin were taken from the 1991-report of Romijn et al. and the associated publications [20,53]. Table 18 summarises the MPC-values derived in 1994. According to the authors, the low MPC for secondary poisoning of aldrin (0.0012 and 0.0037 $mg/kg_{dwt\ soil}$) were caused by one very low toxicity value for birds. Because the other MPCs for secondary poisoning were less critical, the MPCs for aldrin and dieldrin were set to the value for direct ecotoxicity obtained for dieldrin. For endrin, the value based on equilibrium partitioning was selected. Note that these values were revised in 2001 (see section 3.1). In 2002, $SRC_{soil,\ secpois}$ were derived for aldrin/dieldrin and endrin of 0.2 and 0.17 $mg/kg_{dwt\ soil}$, respectively [16].

Table 18 Overview of MPC-values for drins derived in 1994 [6,22]. Corresponding values derived in 2001 are given between brackets. All values in $mg/kg_{dwt\ soil}$.

Type of MPC (based on)	dieldrin	aldrin	endrin
$MPC_{soil,\ eco}$ (direct ecotoxicity)	0.05 (0.05)	0.05 (0.05)	0.00095 (0.00095)
$MPC_{soil,\ secpois}$ (birds)	0.067	0.0012	0.030
$MPC_{soil,\ secpois}$ (mammals)	0.081	0.078	0.017
$MPC_{soil,\ secpois}$ (birds+mammals)	0.087	0.0037	0.020
MPC_{soil} (eco+secpois)	0.052	0.011	0.00095
MPC_{soil} (EqP)	0.67 (0.038)	0.12 (0.043)	0.0029 (0.0026)

3.2.2 Evaluation and additional assessment for drins

3.2.2.1 Choice of the BSAF

Concerning the earthworm BSAF of dieldrin, a similar situation exists as for DDT (see section 2.2.3.2). Previously used BSAFs are geometric mean and maximum values of 0.33 and 1.5 $kg_{dwt\ soil}/kg_{wwt\ worm}$ at 10% OM [19,20], and default values of 1 and 10 $kg_{dwt\ soil}/kg_{wwt\ worm}$ [6]. Most studies cited in section 2.2.3.2 for DDT and metabolites, also provide data on dieldrin. Additional data were found in [54,55], reported lipid based residues in worms were converted to wet weight based values using a default lipid content of 1% [54]. In line with the approach for DDT, BSAFs were normalised to soil OM content. The available data are summarised in Table 19.

Table 19 Summary of BSAFs for dieldrin in worms for soils with different organic matter content as reported in the literature. Field = worms sampled from contaminated site, Lab = laboratory exposure of worms to contaminated field soils. BSAFs are shown based on dry weight concentrations in soil and normalised to organic matter content (OM).

BSAF		OM	Exposure	Reference
$kg_{dwt\ soil}/kg_{wwt\ worm}$	$kg_{soil\ OM}/kg_{wwt\ worm}$	[%]	type	
0.24	0.0096	4	Field	[35]
0.41	0.0203	5	Field	[41]
0.14	0.0130	9	Field	[41]
1.58	0.0695	4.4	Lab[a]	[36]
0.66	0.0354	5.4	Lab[a]	[36]
0.12	0.0131	11.2	Lab[a]	[55]
0.37	0.0530	14.5	Lab[a]	[55]
0.24	0.0349	14.5	Lab[a]	[55]
0.032	0.0035	11.2	Field	[54]
0.020	0.0022	11.2	Field	[54]

a: worms from breeding culture

The geometric mean OM-normalised BSAF is 0.016 $kg_{soil\ OM}/kg_{wwt\ worm}$, this value is used for further calculations.

3.2.2.2 Risks for worm-eating birds

The available data on toxicity of drins for bird are presented in Appendix 4. Data for aldrin and endrin are taken from Van de Plassche [6,22], data for dieldrin from Romijn et al. [20,53] and the US EPA Eco-SSL report [52]. Mortality data were included, because this endpoint is sometimes more sensitive than sublethal parameters. The lowest available chronic value per species was selected.

From the data in Appendix 4 (Table A4.1) it appears that there are few data on birds for aldrin and endrin. For aldrin, the NOAECs of 0.05 mg/kg_{fd} for *Coturnix japonica* and 0.5 mg/kg_{fd} for *Phasianus colchicus* that were used in 1994 have been extrapolated from high-effect LOAECs using an assessment factor of 10 [6,22]. These data are therefore not used in the present assessment. The NOAECs for endrin were obtained using the LOAECs with an assessment factor of two, which according to the current guidance is appropriate in case the effect level is <20%. In view of the reported effect levels (see Appendix 4, Table A4.2), this approach is accepted for *Anas platyrhynchos*, *C. japonica* and *P. colchicus*, but not for *Otis asio*. *Table 20* lists the remaining NOAEC-data for birds.

As indicated in section 2.3.4.3, an assessment factor of 30 is applied to the NOAEC of a chronic reproduction study, which according to OECD guidelines lasts at least 20 weeks. The present dataset also contains bird studies that can be considered as short-term (24 d NOEC of dieldrin for *A. platyrhynchos*) or semi-chronic, i.e. lasting 8 - 16 weeks (*Columba livia*, *C. japonica*). As for DDT, these NOAEC-values are used with an assessment factor of 30, although this may not be sufficient to cover the uncertainty with respect to study duration. For *A. platyrhynchos*, some confidence can be found in the fact that all other studies with dieldrin, including those with longer exposure, resulted in higher NOAECs.

Table 20 Lowest NOAEC-values per species for dieldrin and endrin from long-term tests with birds and MPC$_{\text{oral, bird}}$ values using the default assessment factor of 30.

Species	Exposure time	Endpoint	NOAEC [mg/kg$_{\text{fd}}$]	MPC$_{\text{oral, bird}}$ AF 30 [mg/kg$_{\text{fd}}$]
dieldrin				
Anas platyrhynchos	24 d	mortality	0.3	0.010
Colinus virginianus	34 w	mortality	2.5	0.083
Columba livia	8 w	mortality	25[#]	0.83
Coturnix japonica	16 w	reproduction	5	0.17
Gallus domesticus	13 m	reproduction	10	0.33
Numida meleagris	21 m	mortality, reproduction	1.5	0.050
Phasianus colchicus		reproduction	2	0.067
Tyto alba	2 y	mortality, eggs	≥ 0.58	≥ 0.019
Quail (not spec.) [a]	162 d	mortality	0.5	0.017
endrin				
Anas platyrhynchos	12 w	reproduction	1.5	0.050
Coturnix japonica	162 d		0.25	0.0083
Phasianus colchicus			1	0.033

recalculated from dietary dose using information in Eco-SSL-report
a: interpreted as *C. japonica* in [6,22]

Dieldrin

The MPC$_{\text{oral, bird, AF}}$ for dieldrin is 0.3 / 30 = 0.01 mg/kg$_{\text{fd}}$ = 10 µg/kg$_{\text{fd}}$. Based on the geometric mean of unbound NOAECs, the SRC$_{\text{oral, bird, AF}}$ is 2.5 / 30 = 0.08 mg/kg$_{\text{fd}}$ = 80 µg/kg$_{\text{fd}}$. With a BSAF of 0.016 kg$_{\text{soil OM}}$/kg$_{\text{wwt worm}}$ (see 3.2.2.1), the **MPC$_{\text{soil, secpois, bird, AF}}$ is 625 µg/kg$_{\text{soil OM}}$**. The **SRC$_{\text{soil, secpois, bird, AF}}$ is 5000 µg/kg$_{\text{dwt soil}}$**. Expressed on the basis of Dutch standard soil with 10% OM, these values are equivalent to 63 and 500 µg/kg$_{\text{dwt soil}}$, respectively (rounded values).

Because for dieldrin more than eight test results are available, the data are also used in an SSD-approach using the program MOSAIC-SSD [45]. In this case, an assessment factor of 3 is used on the individual NOAECs. This results in an HC5 for dieldrin (with 95% confidence limits) of 93.2 µg/kg$_{\text{fd}}$ (95% CL 39.9 - 441) and an HC50 of 861 µg/kg$_{\text{fd}}$ (95% CL 348 - 2208). Leaving the NOAEC for the unspecified quail out of consideration, or using it as lowest value for either *C. japonica* or *C. virginianus* only slightly changes the resulting HC-values. Because the number of data is only at the minimum, an assessment factor of 5 is applied for derivation of the MPC$_{\text{soil, secpois, bird SSD}}$. With the BSAF of 0.016 kg$_{\text{soil OM}}$/kg$_{\text{wwt worm}}$, the **MPC$_{\text{soil, secpois, bird, SSD}}$** is 1165 µg/kg$_{\text{soil OM}}$ and the **SRC$_{\text{soil, secpois, bird, SSD}}$** is 0.861 / 0.016 = 53.8 mg/ kg$_{\text{soil OM}}$. Expressed on the basis of Dutch standard soil with 10% OM, these values are equivalent to **120** and **5400 µg/kg$_{\text{dwt soil}}$**, respectively (rounded values).

Endrin

For endrin, the $MPC_{oral,\ bird,\ AF}$ is 0.25 / 30 = 0.008 mg/kg_{fd} = 8 $\mu g/kg_{fd}$. Using the geometric mean of the NOEAC-values with an assessment factor of 30, the $SRC_{oral,\ bird,\ AF}$ is 0.024 mg/kg_{fd} = 24 $\mu g/kg_{fd}$. In accordance with [16], the BSAF for dieldrin is also used for endrin. This results in an $MPC_{soil,\ secpois,\ bird,\ AF}$ of 500 $\mu g/kg_{soil\ OM}$ and an $SRC_{soil,\ secpois,\ bird,\ AF}$ of 1500 $\mu g/kg_{soil\ OM}$. Expressed on the basis of Dutch standard soil with 10% OM, these values are equivalent to **50** and **150** **$\mu g/kg_{dwt\ soil}$**, respectively.

3.2.2.3 Risks for worm-eating mammals

Similar to what is described above, the available data for mammals are presented in Appendix 5, table A5.1 to A5.4. According to the guidance, an assessment factor of 30 should be put on chronic test results, and a factor of 90 on results of 90-days tests. Table 21 summarises the lowest NOAEL and NOAEC-values per species.

Table 21 Lowest NOAEC-values per species for dieldrin, aldrin and endrin from long-term tests with mammals and $MPC_{oral,\ mammal}$ values using the default assessment factor of 30 or 90.

Species	Exposure time	Endpoint	NOAEC [mg/kg_{fd}]	$MPC_{oral,\ bird}$ AF 30 or 90 [mg/kg_{fd}]
Dieldrin				
Canis familiaris	104 w	body weight	1.2#	0.040
Damaliscus dorcas	90 d	mortality	15	0.17
Macaca mulatta	6 y	reproduction	1	0.033
Mus musculus	2 y	mortality	1	0.033
Odocoileus virginianus	3 y	body weight	< 4.5#	< 0.15
Ovis aries	32 w	body weight	28#	0.93
Rattus norvegicus	life time	reproduction	1.25	0.042
Aldrin				
Canis domesticus	1 y	mortality	3	0.10
Mus musculus	6 gen.	reproduction	3	0.10
Oryctolagus cuniculis	90 d	mortality	40	1.3
Rattus norvegicus	3 gen.	reproduction	1.25	0.042
Endrin				
Canis domesticus	16-19 m	growth	3	0.10
Mus musculus	6 gen.	reproduction	47	1.6
Rattus norvegicus	3 gen.	reproduction	1	0.033

recalculated from dietary dose using information in Eco-SSL-report

Dieldrin

For dieldrin, based on the lowest NOAEC of 1 mg/kg_{fd}, the resulting $MPC_{oral,\ mammal,\ AF}$ is 0.033 mg/kg_{fd} = 33 $\mu g/kg_{fd}$ for mouse and rhesus monkey. Using the bound data, the $SRC_{oral,\ bird}$ is 0.081 mg/kg_{fd} = 81 $\mu g/kg_{fd}$. Using the BSAF of 0.016 $kg_{soil\ OM}/kg_{wwt\ worm}$ (see 3.2.2.1), the resulting $MPC_{soil,\ secpois,\ mammal,\ AF}$ is 2063 $\mu g/kg_{soil\ OM}$ and the $SRC_{soil,\ secpois,\ mammal,\ AF}$ is 5063 $\mu g/kg_{soil\ OM}$. Expressed on the basis of Dutch standard soil with 10% OM, these values are equivalent to 200 and 500 $\mu g/kg_{dwt\ soil}$, respectively (rounded values).

The data for dieldrin, including the <-value, are also used to construct an SSD [45]. Because tests of different duration are used, the SSD is constructed using the NOAECs from Table 21 with an assessment factor of 9 for the 90-days test, and a factor of 3 for the other tests. The HC5 (with 95% confidence limits) is estimated as 103 µg/kg$_{\text{fd}}$ (95% CL 67.5 - 326) and the HC50 as 741 µg/kg$_{\text{fd}}$ (95% CL 359 - 1913). As for birds, only few data are available, and an assessment factor of 5 is used for derivation of the MPC$_{\text{soil secpois, mammal, SSD}}$. With this assessment factors and the BSAF of 0.016 kg$_{\text{soil OM}}$/kg$_{\text{wwt worm}}$, the **MPC$_{\text{soil, secpois, mammal, SSD}}$** is 1290 µg/kg$_{\text{soil OM}}$. The **SRC$_{\text{soil, secpois, mammal, SSD}}$** is 0.741 / 0.016 = 46.3 mg/kg$_{\text{soil OM}}$. These values are equivalent to **130** and **4600 µg/kg$_{\text{dwt soil}}$**, respectively, for Dutch standard soil (rounded values).

Because these values are close to those derived for birds, both datasets may also be combined into one SSD. This results in the same HC5 and HC50, but with smaller confidence limits. The HC5 is 96.1 µg/kg$_{\text{fd}}$ (95% CL 51.4 - 230) and the HC50 is 800 µg/kg$_{\text{fd}}$ (95% CL 424 - 1578). Because the number of datapoints is twice as high and the uncertainty has decreased, a lower assessment factor of 3 is now considered for derivation of the **MPC$_{\text{soil, secpois, SSD}}$** leading to a value of 2002 µg/kg$_{\text{soil OM}}$. The **SRC$_{\text{soil, secpois, SSD}}$** is 50 mg/kg$_{\text{soil OM}}$. Converted to Dutch standard soil, these values are **200** and **5000 µg/kg$_{\text{dwt soil}}$**, respectively.

Aldrin
For aldrin the lowest MPC$_{\text{oral, mammal, AF}}$ is 42 µg/kg$_{\text{fd}}$ for the rat. The SRC$_{\text{oral, mammal, AF}}$ is 120 µg/kg$_{\text{fd}}$. Using the BSAF for dieldrin, the **MPC$_{\text{soil, secpois, mammal, AF}}$** is 2625 µg/kg$_{\text{soil OM}}$ and the **SRC$_{\text{soil, secpois, mammal, AF}}$** is 7.5 mg/kg$_{\text{soil OM}}$. This is equivalent to **260** (rounded value) and **750 µg/kg$_{\text{dwt soil}}$** in Dutch standard soil.

Endrin
For endrin, an assessment factor 30 is used, which results in a lowest MPC$_{\text{oral, mammal, AF}}$ of 33 µg/kg$_{\text{fd}}$ for the rat. The SRC$_{\text{oral, mammal, AF}}$ is 170 µg/kg$_{\text{fd}}$. Using the BSAF for dieldrin, the **MPC$_{\text{soil, secpois, mammal, AF}}$** is 2063 µg/kg$_{\text{soil OM}}$ and the **SRC$_{\text{soil, secpois, mammal, AF}}$** is 10.6 mg/kg$_{\text{soil OM}}$. This is equivalent to **200** and **1100 µg/kg$_{\text{dwt soil}}$** in Dutch standard soil (rounded values).

3.3 Summary and conclusions on drins

In the absence of new data, the ecological risk limits based on direct ecotoxicity of drins to soil organisms cannot be better underpinned. Improving the aquatic dataset does not seem to be possible either. Based on the available data for dieldrin, there is no obvious difference in sensitivity between birds and mammals.

Taking the SSD-based results for dieldrin, an MPC$_{\text{soil, secpois}}$ of 200 µg/kg$_{\text{dwt soil}}$ is derived for worm-eating birds and mammals together. This is a factor of 4 higher than the previously derived MPC$_{\text{soil, eco}}$ of 50 µg/kg$_{\text{dwt soil}}$ for direct ecotoxicity. The SRC$_{\text{soil, secpois}}$ for worm-eating birds and mammals is 5000 µg/kg$_{\text{dwt soil}}$, which is also much higher than the previously derived value of 220 µg/kg$_{\text{dwt soil}}$ based on direct ecotoxicity. Still it can be argued that secondary poisoning is indeed critical as compared to direct ecotoxicity, since the geometric mean chronic NOEC for direct ecotoxicity is 19000 µg/kg$_{\text{dwt soil}}$ (see 3.1). Due to limited data, a full comparison cannot be made for aldrin and endrin. However, the calculations indicate that results are similar to those of dieldrin. In line with the previous evaluations, it is proposed to use one combined risk limit for the sum of dieldrin and aldrin. For this, the risk limits derived for dieldrin are most appropriate, because they are based on a more extensive dataset.

Biomagnification through the terrestrial food chain is relevant for drins and an additional factor will be needed to derive risk limits that also protect higher predatory birds and mammals. However, screening of the literature did not result in studies to underpin such a factor. Therefore, a factor of 10 is proposed in line with DDT and metabolites. For dieldrin + aldrin, this would lead to tentative **$MPC_{soil,\ secpois}$** and **$SRC_{secpois,\ soil}$**-values for higher predators of **20** and **500 µg/kg$_{dwt\ soil}$**, respectively. In that case, the current MPC_{soil} would possibly be (slightly) underprotective. The MPC_{soil} of endrin is sufficiently protective for higher predators, but the SRC_{soil} probably not.

The derived $MPC_{soil,\ secpois}$ and $SRC_{secpois,\ soil}$ for worm-eating birds and mammals are presented in Table 22 and compared with the current values based on direct ecotoxicity. The intermediate ecological level is calculated as the geometric mean of MPC and SRC. The current background value for drins (combined) is 15 µg/kg$_{dwt\ soil}$, for standard soil with 10% OM [50,51]. The sum of the current individual $MPC_{soil,\ eco}$-values and proposed values for $MPC_{soil,\ secpois}$ are higher than this value.

Table 22 Summary of derived risk limits for drins based on secondary poisoning of worm-eating birds and higher predatory birds. Risk limits are derived using statistical extrapolation (dieldrin + aldrin) or based on the lowest available NOAEC (endrin). All values in µg/kg$_{dwt\ soil}$, based on Dutch standard soil with 10% organic matter. Current risk limits based on direct ecotoxicity are presented as well, based on [1,51].

Risk limit based on	MPC_{soil}	SRC_{soil}	Intermediate ecological level
dieldrin + aldrin			
worm-eating birds+mammals	200	5000	1000
higher predatory birds + mammals	20	500	100
current value based on direct ecotoxicity^{a}	50	220	40 (sum drins)
endrin			
worm-eating birds	50	150	90
higher predatory birds + mammals	5.0	15	9.0
current value based on direct ecotoxicity^{a}	0.95	95	40 (sum drins)

a: MPC and SRC-values from [1], intermediate ecological values from [51].

4 Conclusions

In this report, the scientific basis of the Dutch ecological risk limits for DDT, DDT-metabolites and drins in soil was evaluated. The current Maximum Permissible Concentration (MPC) and Serious Risk Concentration (SRC) were derived in 2001 considering data on direct ecotoxicity. Hardly any new experiment terrestrial ecotoxicity data have become available for both groups of compounds since then and it is concluded that the dataset is too small to derive reliable risk limits for soil inhabiting organisms. Some data have become available for aquatic organisms, but it is not expected that these data will lead to a marked change in the outcome. Moreover, in view of the characteristics of the compounds, secondary poisoning of birds and mammals should be included in the derivation of ecological risk limits for soil.

For DDT, the current MPC and SRC for soil are 10 and 1000 $\mu g/kg_{dwt\ soil}$ for soil with 10% organic matter. The newly derived $MPC_{soil,\ secpois}$ for DDT and metabolites based on secondary poisoning of worm-eating birds is 20 $\mu g/kg_{dwt\ soil}$. The SRC is 3800 $\mu g/kg_{dwt\ soil}$. For higher predatory birds, an additional factor of 10 is proposed to account for biomagnification in the terrestrial food chain and the $MPC_{soil,\ secpois}$ and $SRC_{soil,\ secpois}$ including these species would be 2.0 and 380 $\mu g/kg_{dwt\ soil}$. It is concluded that the current values for DDT are protective for worm-eating birds and mammals, but probably not for higher predators. This should be taken into account when deciding on the re-use of soil in areas where protection of these predators is relevant.

The current MPC and SRC for dieldrin and aldrin are 50 and 220 $\mu g/kg_{dwt\ soil}$, the newly derived values for the $MPC_{soil,\ secpois}$ and $SRC_{soil,\ secpois}$ based on secondary poisoning of worm-eating birds are 200 and 5000 $\mu g/kg_{dwt\ soil}$. The $MPC_{soil,\ secpois}$ and $SRC_{soil,\ secpois}$ including predatory bird and mammal species would be 20 and 500 $\mu g/kg_{dwt\ soil}$. It is concluded that the current values are protective for worm-eating birds and mammals and most likely also for higher predators.

For endrin, the current MPC and SRC for soil are 9.5 and 95 $\mu g/kg_{dwt\ soil}$. The newly derived $MPC_{soil,\ secpois}$ based on secondary poisoning of worm-eating birds is 50 $\mu g/kg_{dwt\ soil}$. The SRC is 150 $\mu g/kg_{dwt\ soil}$. The $MPC_{soil,\ secpois}$ and $SRC_{soil,\ secpois}$ for predators would be 5.0 and 15 $\mu g/kg_{dwt\ soil}$. It is concluded that the current values for endrin are protective for worm-eating birds and mammals, but probably not for higher predators at the level of the SRC. This information should be taken into account when considering the options for re-use of soil.

A summary of the newly derived risk limits and current values is presented in Table 23.

Table 23 Summary of derived risk limits for the sum of DDT and metabolites and drins, based on secondary poisoning of worm-eating birds and mammals and higher predators. All values in µg/kg$_{dwt\ soil}$ for Dutch standard soil with 10% organic matter.

Compound	MPC$_{soil}$			SRC$_{soil}$		
	current	proposed		current	proposed	
		worm-eater	higher predator		worm-eater	higher predator
sum DDT and metabolites	10 (DDT) 13 (DDE) 21 (DDD)	20	2.0	1000 (DDT) 1300 (DDE) 34000 (DDD)	3800	380
dieldrin + aldrin	50	200	20	220	5000	500
endrin	9.5	50	5.0	95	150	15

References

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Appendix 1. Overview of potentially relevant aquatic endpoints from the US EPA Ecotox database

NR = not reported
Exposure type: R = renewal, S = static, F = flow through
Media type: SW = saltwater, FW = freshwater
Endpoint: MOR = mortality, REP = reproduction

Table A1.1 Acute toxicity data from tests with duration of 5 days or less, with analysis of test concentrations.

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Crustaceans										
Crangon septemspinosa	R	SW	0.625	LC50	MOR	1.1	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Crangon septemspinosa	R	SW	0.625	LC50	MOR	1.9	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Crangon septemspinosa	R	SW	0.6667	LC50	MOR	0.9	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Crangon septemspinosa	R	SW	0.8333	LC50	MOR	1.8	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Crangon septemspinosa	R	SW	0.875	LC50	MOR	0.9	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Crangon septemspinosa	R	SW	4	LC50	MOR	0.4	McLeese,D.W., and C.D. Metcalfe	Toxicities of Eight Organochlorine Compounds in Sediments and Seawater to Crangon septemspinosa	Bull. Environ. Contam. Toxicol.25(6): 921-928	1980
Orconectes nais	S	FW	4	LC50	MOR	100	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Palaemonetes kadiakensis	F	FW	5	LC50	MOR	1.3	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Palaemonetes kadiakensis	S	FW	5	LC50	MOR	1	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Ceriodaphnia dubia	R	FW	2	EC50	MOR	0.83	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Daphnia pulex	NR	FW	2	EC50	MOR	0.4	Cope,O.B.	Contamination of the Freshwater Ecosystem by Pesticides	J. Appl. Ecol.3:33-44	1966
Hyalella azteca	S	FW	4	LC50	MOR	0.36	Ding,Y., P.F. Landrum, J. You, A.D. Harwood, and M.J. Lydy	Use of Solid Phase Microextraction to Estimate Toxicity: Relating Fiber Concentrations to Toxicity - Part I	Environ. Toxicol. Chem.31(9): 2159-2167	2012
Hyalella azteca	R	FW	4	LC50	MOR	0.17	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000
Gammarus fasciatus	F	FW	5	LC50	MOR	0.6	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Gammarus fasciatus	S	FW	4	LC50	MOR	3.2	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Fish										
Encrasicholina purpurea	S	SW	0.5	LC50	MOR	1	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970
Kuhlia sandvicensis	R	SW	2	LC50	MOR	6.3	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970
Kuhlia sandvicensis	R	SW	4	LC50	MOR	3.9	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970
Kuhlia sandvicensis	S	SW	1	LC50	MOR	12	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970
Oreochromis mossambicus	R	FW	2	LC50	MOR	12	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970
Oreochromis mossambicus	R	FW	4	LC50	MOR	7	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honolulu, HI:38 p.	1970

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Oreochromis mossambicus	S	FW	1	LC50	MOR	20	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Barbus dorsalis	S	FW	1	LC50*	MOR	86	Rao,T.S., S. Dutt, and K. Mangaiah	TLM Values of Some Modern Pesticides to the Freshwater Fish - Puntius puckelli	Environ. Health (London)9:103-109	1967
Barbus dorsalis	S	FW	2	LC50*	MOR	86	Rao,T.S., S. Dutt, and K. Mangaiah	TLM Values of Some Modern Pesticides to the Freshwater Fish - Puntius puckelli	Environ. Health (London)9:103-109	1967
Barbus dorsalis	S	FW	4	LC50*	MOR	48	Rao,T.S., S. Dutt, and K. Mangaiah	TLM Values of Some Modern Pesticides to the Freshwater Fish - Puntius puckelli	Environ. Health (London)9:103-109	1967
Misgurnus anguillicaudatus	S	NR	1	LC50	MOR	350	Yang,C.F., and Y.P. Sun	Partition Distribution of Insecticides as a Critical Factor Affecting Their Rates of Absorption from Water and Relative Toxicities to Fish	Arch. Environ. Contam. Toxicol.6(2/3): 325-335	1977
Ictalurus punctatus	NR	FW	2	EC50	MOR	12	Cope,O.B.	Contamination of the Freshwater Ecosystem by Pesticides	J. Appl. Ecol.3:33-44	1966
Lepomis macrochirus	NR	FW	2	EC50	MOR	6	Cope,O.B.	Contamination of the Freshwater Ecosystem by Pesticides	J. Appl. Ecol.3:33-44	1966
Poecilia reticulata	R	FW	2	LC50	MOR	8	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Poecilia reticulata	R	FW	4	LC50	MOR	3	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Poecilia reticulata	S	FW	1	LC50	MOR	20	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Pimephales promelas	F	FW	2	LC50*	MOR	16.7	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969
Pimephales promelas	F	FW	2	LC50*	MOR	18.5	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969
Pimephales promelas	F	FW	2	LC50*	MOR	19	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969
Pimephales promelas	F	FW	4	LC50*	MOR	15.5	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969
Pimephales promelas	F	FW	4	LC50*	MOR	17.6	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Pimephales promelas	F	FW	4	LC50*	MOR	8.5	Solon,J.M., J.L. Lincer, and J.H. Nair III	The Effect of Sublethal Concentration of LAS on the Acute Toxicity of Various Insecticides to the Fathead Minnow (Pimephales promelas Rafinesque)	Water Res.3(10): 767-775	1969
Oncorhynchus mykiss	NR	FW	2	EC50	MOR	5	Cope,O.B.	Contamination of the Freshwater Ecosystem by Pesticides	J. Appl. Ecol.3:33-44	1966
Oncorhynchus kisutch	F	FW	1.0417	LT50	MOR	3.2	Halter,M.T., and H.E. Johnson	Acute Toxicities of a Polychlorinated Biphenyl (PCB) and DDT Alone and in Combination to Early Life Stages of Coho Salmon (Oncorhynchus kisutch)	J. Fish. Res. Board Can.31(9): 1543-1547	1974
Oncorhynchus kisutch	F	FW	1.0417	LT50	MOR	3.3	Halter,M.T., and H.E. Johnson	Acute Toxicities of a Polychlorinated Biphenyl (PCB) and DDT Alone and in Combination to Early Life Stages of Coho Salmon (Oncorhynchus kisutch)	J. Fish. Res. Board Can.31(9): 1543-1547	1974
Oncorhynchus kisutch	F	FW	2.2917	LT50	MOR	1.4	Halter,M.T., and H.E. Johnson	Acute Toxicities of a Polychlorinated Biphenyl (PCB) and DDT Alone and in Combination to Early Life Stages of Coho Salmon (Oncorhynchus kisutch)	J. Fish. Res. Board Can.31(9): 1543-1547	1974
Oncorhynchus kisutch	F	FW	2.2917	LT50	MOR	1.9	Halter,M.T., and H.E. Johnson	Acute Toxicities of a Polychlorinated Biphenyl (PCB) and DDT Alone and in Combination to Early Life Stages of Coho Salmon (Oncorhynchus kisutch)	J. Fish. Res. Board Can.31(9): 1543-1547	1974
Oncorhynchus mykiss	F	FW	5	LC50	MOR	2.26	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Gambusia affinis	S	FW	1	LC50	MOR	70	Joshi,A.G., and M.S. Rege	Acute Toxicity of Some Pesticides & a Few Inorganic Salts to the Mosquito Fish Gambusia affinis (Baird & Girard)	Indian J. Exp. Biol.18:435-437	1980
Gambusia affinis	S	FW	2	LC50	MOR	60	Joshi,A.G., and M.S. Rege	Acute Toxicity of Some Pesticides & a Few Inorganic Salts to the Mosquito Fish Gambusia affinis (Baird & Girard)	Indian J. Exp. Biol.18:435-437	1980
Gambusia affinis	S	FW	3	LC50	MOR	55	Joshi,A.G., and M.S. Rege	Acute Toxicity of Some Pesticides & a Few Inorganic Salts to the Mosquito Fish Gambusia affinis (Baird & Girard)	Indian J. Exp. Biol.18:435-437	1980
Gambusia affinis	S	FW	4	LC50	MOR	40	Joshi,A.G., and M.S. Rege	Acute Toxicity of Some Pesticides & a Few Inorganic Salts to the Mosquito Fish Gambusia affinis (Baird & Girard)	Indian J. Exp. Biol.18:435-437	1980
Gambusia affinis	R	FW	2	LC50	MOR	46	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Gambusia affinis	R	FW	4	LC50	MOR	20	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Gambusia affinis	S	FW	1	LC50	MOR	560	Nunogawa,J.H., N.C.,Jr. Burbank, R.H.F. Young, and L.S. Lau	Relative Toxicities of Selected Chemicals to Several Species of Tropical Fish	Water Resour.Res.Ctr., Univ.of Hawaii, Honululu, HI:38 p.	1970
Insects										
Baetis sp.	NR	FW	2	EC50	MOR	12	Cope,O.B.	Contamination of the Freshwater Ecosystem by Pesticides	J. Appl. Ecol.3:33-44	1966

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Chironomus dilutus	S	FW	4	LC50	MOR	0.71	Ding,Y., P.F. Landrum, J. You, A.D. Harwood, and M.J. Lydy	Use of Solid Phase Microextraction to Estimate Toxicity: Relating Fiber Concentrations to Toxicity - Part I	Environ. Toxicol. Chem.31(9): 2159-2167	2012
Chironomus dilutus	S	FW	4	LC50	MOR	3.88	Harwood,A.D., J. You, and M.J. Lydy	Temperature as a Toxicity Identification Evaluation Tool for Pyrethroid Insecticides: Toxicokinetic Confirmation	Environ. Toxicol. Chem.28(5): 1051-1058	2009
Chironomus dilutus	S	FW	4	LC50	MOR	6.26	Harwood,A.D., J. You, and M.J. Lydy	Temperature as a Toxicity Identification Evaluation Tool for Pyrethroid Insecticides: Toxicokinetic Confirmation	Environ. Toxicol. Chem.28(5): 1051-1058	2009
Ischnura verticalis	S	FW	4	LC50	MOR	56	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Echinoderms										
Strongylocentrotus droebachiensis	S	SW	0.0542	EC50	REP	3	Dinnel,P.A., J.M. Link, Q.J. Stober, M.W. Letourneau, and W.E. Roberts	Comparative Sensitivity of Sea Urchin Sperm Bioassays to Metals and Pesticides	Arch. Environ. Contam. Toxicol.18(5): 748-755	1989
Strongylocentrotus purpuratus	S	SW	0.0542	EC50	REP	NR	Dinnel,P.A., J.M. Link, Q.J. Stober, M.W. Letourneau, and W.E. Roberts	Comparative Sensitivity of Sea Urchin Sperm Bioassays to Metals and Pesticides	Arch. Environ. Contam. Toxicol.18(5): 748-755	1989

Table A1.2 Chronic toxicity data from tests with duration of 7 days or more, with analysis of test concentrations.

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Crustaceans										
Ceriodaphnia dubia	R	FW	7	NOEC	REP	1.74	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Ceriodaphnia dubia	R	FW	7	NOEC	MOR	1.74	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Ceriodaphnia dubia	R	FW	7	MATC	MOR	2.49	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Ceriodaphnia dubia	R	FW	7	LOEC	MOR	3.57	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Ceriodaphnia dubia	R	FW	7	LOEC	REP	3.57	Brooke,L.	Acute and Chronic Toxicity of Several Pesticides to Five Species of Aquatic Organisms	U.S.EPA Contract No.68-C1-0034, Work Assignment No.2, to Mr.Robert Spehar, U.S.EPA, Duluth, MN:31 p.	1993
Diporeia sp.	R	FW	10	EC50	MOR	0.67	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000
Diporeia sp.	R	FW	10	LC50	MOR	2.16	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000
Diporeia sp.	R	FW	28	EC50	MOR	0.07	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Diporeia sp.	R	FW	28	LC50	MOR	0.26	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000
Hyalella azteca	F	FW	10	LC50	MOR	0.07	Hoke,R.A., G.T. Ankley, A.M. Cotter, T. Goldenstein, P.A. Kosian, G.L. Phipps, and F.M. Vandermeiden	Evaluation of Equilibrium Partitioning Theory for Predicting Acute Toxicity of Field-Collected Sediments Contaminated with DDT, DDE and DDD to the	Environ. Toxicol. Chem.13:157-166	1994
Hyalella azteca	F	FW	10	LC50	MOR	0.07	Phipps,G.L., V.R. Mattson, and G.T. Ankley	Relative Sensitivity of Three Freshwater Benthic Macroinvertebrates to Ten Contaminants	Arch. Environ. Contam. Toxicol.28(3): 281-286	1995
Hyalella azteca	S	FW	10	LC50	MOR	0.094	Ding,Y., P.F. Landrum, J. You, A.D. Harwood, and M.J. Lydy	Use of Solid Phase Microextraction to Estimate Toxicity: Relating Fiber Concentrations to Toxicity - Part I	Environ. Toxicol. Chem.31(9): 2159-2167	2012
Hyalella azteca	R	FW	10	LC50	MOR	0.1	Lotufo,G.R., P.F. Landrum, M.L. Gedeon, E.A. Tigue, and L.R. Herche	Comparative Toxicity and Toxicokinetics of DDT and Its Major Metabolites in Freshwater Amphipods	Environ. Toxicol. Chem.19(2): 368-379	2000
Insects										
Chironomus dilutus	S	FW	10	NR-ZERO	MOR	0.12	Ding,Y., P.F. Landrum, J. You, A.D. Harwood, and M.J. Lydy	Use of Solid Phase Microextraction to Estimate Toxicity: Relating Fiber Concentrations to Toxicity - Part I	Environ. Toxicol. Chem.31(9): 2159-2167	2012
Chironomus dilutus	S	FW	10	LC50	MOR	0.49	Ding,Y., P.F. Landrum, J. You, A.D. Harwood, and M.J. Lydy	Use of Solid Phase Microextraction to Estimate Toxicity: Relating Fiber Concentrations to Toxicity - Part I	Environ. Toxicol. Chem.31(9): 2159-2167	2012

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Chironomus tentans	F	FW	10	LC50	MOR	1.23	Phipps,G.L., V.R. Mattson, and G.T. Ankley	Relative Sensitivity of Three Freshwater Benthic Macroinvertebrates to Ten Contaminants	Arch. Environ. Contam. Toxicol.28(3): 281-286	1995
Chironomus tentans	NR	FW	10	LC50	MOR	1.25	Hoke,R.A., G.T. Ankley, P.A. Kosian, A.M. Cotter, F.M. Vandermeiden, M. Balcer, G.L. Phipps, and C. West	Equilibrium Partitioning as the Basis for an Integrated Laboratory and Field Assessment of the Impacts of DDT, DDE and DDD in Sediments	Ecotoxicology6(2): 101-125	1997
Molluscs										
Crassostrea virginica	F	SW	84	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Crassostrea virginica	F	SW	84	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Crassostrea virginica	F	SW	168	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Crassostrea virginica	F	SW	168	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Crassostrea virginica	F	SW	252	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Crassostrea virginica	F	SW	252	NOEC	GRO	0.6	Lowe,J.I., P.D. Wilson, A.J. Rick, and A.J.,Jr. Wilson	Chronic Exposure of Oysters to DDT, Toxaphene and Parathion	Proc. Natl. Shellfish. Assoc.61:71-79	1971
Fish										
Oncorhynchus mykiss	F	FW	10	LC50	MOR	0.87	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972
Oncorhynchus mykiss	F	FW	15	LC50	MOR	0.26	Stalling,D.L., and F.L.,Jr. Mayer	Toxicities of PCBs to Fish and Environmental Residues	Environ. Health Perspect.1:159-164	1972

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Oryzias latipes	F	FW	14	LOEC	REP	0.23	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	F	FW	14	NOEC	REP	0.23	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	F	FW	14	LOEC	REP	0.5	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	F	FW	14	NOEC	REP	0.5	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	NR	FW	14	NOEC	REP	0.5	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	14	LOEC	REP	1.37	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	NR	FW	14	LOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	14	NOEC	MPH	1.37	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001

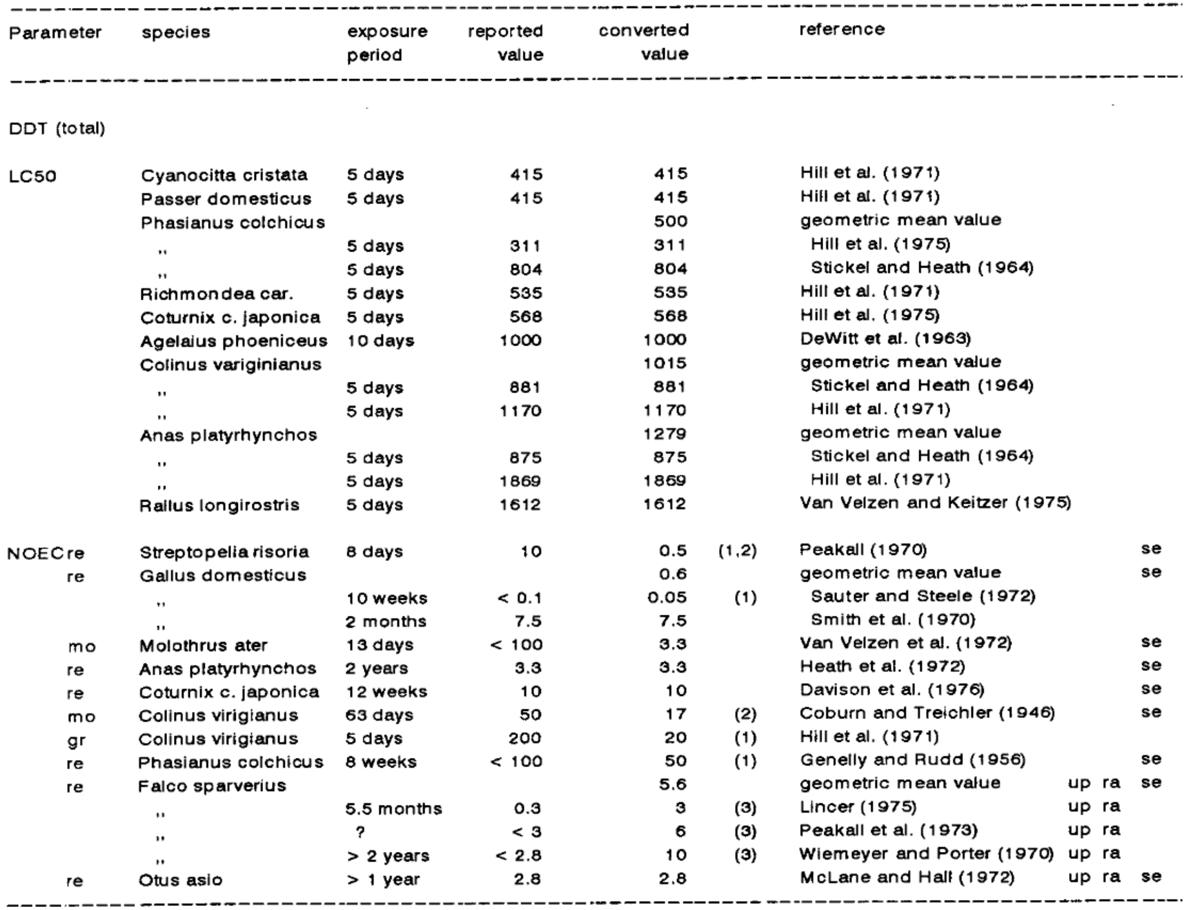
Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Oryzias latipes	F	FW	14	NOEC	REP	1.37	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	NR	FW	14	NOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	14	NOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	14	NOEC	POP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	14	LOEC	POP	4.23	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	14	LOEC	MPH	4.32	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	NR	FW	14	LOEC	REP	4.32	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	56	LOEC	REP	0.3	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Oryzias latipes	F	FW	56	LOEC	REP	0.3	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	F	FW	56	NOEC	MPH	0.69	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	NR	FW	56	NOEC	POP	0.69	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	56	NOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	56	NOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	NR	FW	56	NOEC	REP	1.37	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	56	LOEC	MPH	1.94	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001
Oryzias latipes	F	FW	56	LOEC	REP	1.94	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001

Species Name	Exposure Type	Media Type	Duration [d]	Criterion	Endpoint	Value [µg/L]	Author	Title	Source	Publication Year
Oryzias latipes	NR	FW	56	LOEC	POP	1.94	Cheek,A.O., J.A. Fentress, S.L. Steele, H.L.,Jr. Bart, and M. Brouwer	Models and Murkiness: Evaluating Fish Endocrine Disruption in the Laboratory and the Field	In: Proc. 3rd Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis, MN:141-150	2003
Oryzias latipes	F	FW	56	NOEC	REP	1.94	Cheek,A.O., T.H. Brouwer, S. Carroll, S. Manning, J.A. McLachlan, and M. Brouwer	Experimental Evaluation of Vitellogenin as a Predictive Biomarker for Reproductive Disruption	Environ. Health Perspect.109(7): 681-689	2001

Appendix 2. Toxicity of DDT and metabolites to birds

Table A2.1 Toxicity of DDT to birds as reported by Jongbloed et al. [32]. Data indicated with "up" are additional to those cited by Romijn et al. [20]. Values are reported in mg/kg feed. Conversions are made considering exposure duration and magnitude of effects, see copy of original footnotes (next page).



Parameter	species	exposure period	reported value	converted value		reference			
DDT (total)									
LC50	Cyanocitta cristata	5 days	415	415		Hill et al. (1971)			
	Passer domesticus	5 days	415	415		Hill et al. (1971)			
	Phasianus colchicus			500		geometric mean value			
	,,	5 days	311	311		Hill et al. (1975)			
	,,	5 days	804	804		Stickel and Heath (1964)			
	Richmondea car.	5 days	535	535		Hill et al. (1971)			
	Coturnix c. japonica	5 days	568	568		Hill et al. (1975)			
	Agelaius phoeniceus	10 days	1000	1000		DeWitt et al. (1963)			
	Colinus variginianus			1015		geometric mean value			
	,,	5 days	881	881		Stickel and Heath (1964)			
	,,	5 days	1170	1170		Hill et al. (1971)			
	Anas platyrhynchos			1279		geometric mean value			
	,,	5 days	875	875		Stickel and Heath (1964)			
	,,	5 days	1869	1869		Hill et al. (1971)			
	Rallus longirostris	5 days	1612	1612		Van Velzen and Keitzer (1975)			
NOEC re	Streptopelia risoria	8 days	10	0.5	(1,2)	Peakall (1970)			se
re	Gallus domesticus			0.6		geometric mean value			se
	,,	10 weeks	< 0.1	0.05	(1)	Sauter and Steele (1972)			
	,,	2 months	7.5	7.5		Smith et al. (1970)			
mo	Molothrus ater	13 days	< 100	3.3		Van Velzen et al. (1972)			se
re	Anas platyrhynchos	2 years	3.3	3.3		Heath et al. (1972)			se
re	Coturnix c. japonica	12 weeks	10	10		Davison et al. (1976)			se
mo	Colinus virigianus	63 days	50	17	(2)	Coburn and Treichler (1946)			se
gr	Colinus virigianus	5 days	200	20	(1)	Hill et al. (1971)			
re	Phasianus colchicus	8 weeks	< 100	50	(1)	Genelly and Rudd (1956)			se
re	Falco sparverius			5.6		geometric mean value	up	ra	se
	,,	5.5 months	0.3	3	(3)	Lincer (1975)	up	ra	
	,,	?	< 3	6	(3)	Peakall et al. (1973)	up	ra	
	,,	> 2 years	< 2.8	10	(3)	Wiemeyer and Porter (1970)	up	ra	
re	Otus asio	> 1 year	2.8	2.8		McLane and Hall (1972)	up	ra	se

LC50= (sub)acute mortality, NOEC= no observed effect concentration (effect recorded is specified).
mo=mortality, re=reproduction, gr=growth.
up=update with respect to Romijn et al. (1991b), ra=raptorial species, se=selected NOEC for derivation of a bird NOEC.
SP=sparrowhawk, GO=goshawk, BU=buzzard, KE=kestrel, LO=long-eared owl, TA=tawny owl, BA=barn owl, LI=little owl.

(1) NOEC value derived by applying a factor 2 on the lowest concentration tested, which caused <20% effect relative to the control group, or a factor 3 on the lowest concentration which caused 20-50% effect relative to the control group.
(2) NOEC derived by applying a factor 10 on the value obtained from the literature to compensate for the uncertainty in establishing a (chronic) NOEC from short time (<1 month) studies.
(3) Egg shell thinning may lead to egg breakage when it exceeds 20 %. When possible the NOEC is selcted at this level by extrapolation.

Table A2.2 Effects of DDT, DDD and DDE on reproduction and growth of birds as reported in the Eco-SSL report of the US EPA [24]. No or Lowest Adverse Effect Levels (NOAEL/LOAEL) expressed as dietary dose [mg/kg$_{bw}$ d] are calculated in the Eco-SSL report if study results is reported as dietary concentration [mg/kg$_{diet}$], based on reported or default data on body weight and food ingestion. Shaded columns: when original study results were expressed as daily dose, No or Lowest Observed Adverse Effect Concentrations (NOAEC/LOAEC) expressed as dietary concentration [mg/kg$_{fd}$] were recalculated for the present report using data on body weight and food ingestion. Lowest relevant endpoint per species indicated in bold for dietary concentration. See notes for comments on study results.

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
DDD - Technical	Anas platyrhynchos	1 y	RSUC		10	mg/kg diet	1.100	0.0619		0.473			10		Heath et al, 1969
DDE SO4	Anas platyrhynchos	7 d	ESTH	50		mg/kg diet	1.100	0.0619	2.83			50			Kolaja, 1977
DDE	Anas platyrhynchos	7 d	ESTH		10	mg/kg diet	1.100	0.0619		0.563			10		Kolaja, 1977
DDE	Anas platyrhynchos	14 d	ESTH		40	mg/kg diet	1.100	0.0619		2.25			40		Peakall et al., 1973
p,p'-DDE	Anas platyrhynchos	30 d	ESTH		34	mg/kg diet	1.600	0.0790		1.68			34		Risebrough and Anderson, 1975
p,p'-DDE	Anas platyrhynchos	45 d	ESIN		40	mg/kg diet	1.100	0.0619		2.25			40		Lundholm, 1993
p,p'-DDE	Anas platyrhynchos	45 d	ESIN		40	mg/kg diet	1.100	0.0619		2.25			40		Lundholm, 1985
o,p'-DDE	Anas platyrhynchos	48 d	ESIN		40	mg/kg diet	1.100	0.0619		2.25			40		Lundholm, 1980
p,p'-DDE	Anas platyrhynchos	48 d	ESIN		40	mg/kg diet	1.100	0.0619		2.25			40		Lundholm, 1980
p,p'-DDE	Anas platyrhynchos	50 d	GEGG		39	mg/kg diet	1.100	0.0619		2.2			39		Greenburg et al, 1979
DDE	Anas platyrhynchos	61 d	EGWT		5	mg/kg diet	1.100	0.0619		0.281			5		Vanglider and Peterle, 1983
DDE	Anas platyrhynchos	66 d	EGWT	10		mg/kg diet	1.100	0.0619	0.563			10			Vangilder and Peterle, 1981
DDE	Anas platyrhynchos	66 d	ESTH		10	mg/kg diet	1.100	0.0619		0.563			10		Vangilder and Peterle, 1980
p,p'-DDE	Anas platyrhynchos	76 d	ESTH		40	mg/kg diet	1.100	0.0619		2.25			40		Haegele et al., 1974
p,p'-DDE	Anas platyrhynchos	96 d	ESTH		40	mg/kg diet	1.100	0.0619		2.25		20	40	✓,1	Haegele and Hudson 1974
p,p'-DDE	Anas platyrhynchos	5 mo	ESTH		10	mg/kg diet	1.100	0.0619		0.562		5	10	✓,1	Haseltine et al., 1974
p,p'-DDE	Anas platyrhynchos	2 w	ESTH		40	mg/kg diet	4.000	0.1435		1.44			40		Pritchard et al., 1972
DDE	Anas platyrhynchos	22 w	ESTH	1	5	mg/kg diet	1.100	0.0619	0.0563	0.281		**1**	5	✓	Carlisle et al., 1986
p,p'-DDE	Anas platyrhynchos	1 y	RSUC		10	mg/kg diet	1.100	0.0619		0.563			10		Heath et al, 1969
DDT SO4	Anas platyrhynchos	14 d	ESTH	50		mg/kg diet	1.100	0.0619	2.83			50			Kolaja, 1977
p,p'-DDT	Anas platyrhynchos	14 d	BDWT	100		mg/kg diet	0.092	0.0123	13.4			100			Sifri et al., 1975
DDT	Anas platyrhynchos	14 d	ESTH		10	mg/kg diet	1.100	0.0619		0.563			10		Kolaja, 1977
DDT - Technical	Anas platyrhynchos	343 d	ESWT	2	20	mg/kg diet	1.480	0.0620	0.0754	0.754		2	20	✓	Davison and Sell, 1974
p,p'-DDT	Anas platyrhynchos	343 d	ESTH	2	20	mg/kg diet	1.320	0.1310	0.197	1.965		2	20	✓	Davison and Sell, 1974
p,p'-DDT	Anas platyrhynchos	3 mo	ESTH	2	20	mg/kg diet	1.050	0.0555	0.113	1.13		2	20	✓	Davison and Sell, 1974
DDT	Anas platyrhynchos	6 mo	EGWT		50	mg/kg diet	1.200	0.0655		2.73			50		Kolaja and Hinton, 1979
DDT	Anas platyrhynchos	6 mo	ESTH		50	mg/kg diet	1.100	0.0619		2.81			50		Kolaja and Hinton, 1977
DDT	Anas platyrhynchos	7 w	ESTH		75	mg/kg diet	1.100	0.0619		4.22			75		Kolaja and Hinton, 1976
p,p'-DDT	Anas platyrhynchos	1 y	RSUC	10	40	mg/kg diet	1.100	0.0619	0.563	1.892		10	40		Heath et al, 1969
p,p'-DDE	Anas rubripes	28 d	ESTH		10	mg/kg diet	1.100	0.0619		0.563		< 10	10	2	Longcore et al., 1971
p,p'-DDE	Anas rubripes	8 mo	ESTH		10	mg/kg diet	1.100	0.0619		0.563		< 10	10	2	Longcore and Stendell, 1977
p,p'-DDT	Colinus virginianus	56 d	BDWT	25		mg/kg bw/d	0.193	0.0135	25			≥ 357		✓,3	Sullivan and Scanlon, 1991
p,p'-DDT	Colinus virginianus	56 d	BDWT	25		mg/kg diet	0.207	0.0128	1.55			**≥ 25**		✓,3	Sullivan and Scanlon, 1991

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
o,p'-DDD	Columba livia	5 d	TEDG		0.1	mg/bird/d	0.340	0.0288		0.294		< 3	**3**	2	Dasadhikari, et al, 1996
p,p'-DDE	Coturnix japonica	21 d	BDWT	100		mg/kg diet	0.120	0.0146	12.2			100			Bunyan et al., 1972
p,p'-DDE	Coturnix japonica	21 d	BDWT	150		mg/kg diet	0.126	0.0151	18			150			Bunyan and Page, 1973
p,p'-DDE	Coturnix japonica	74 d	NSTI		100	mg/kg diet	0.100	0.0130		13			100		Cecil et al., 1971
DDE	Coturnix japonica	168 d	TPRD	100	300	mg/kg diet	0.134	0.0190	14.2	42.5		100	300		Robson et al., 1976
DDE	Coturnix japonica	168 d	BDWT	100	300	mg/kg diet	0.134	0.0190	14.2	42.5		100	300		Robson et al., 1976
DDE	Coturnix japonica	5 w	BDWT	200		mg/kg diet	0.154	0.0172	22.4			200			Chang and Stokstad, 1975
DDE	Coturnix japonica	5 w	BDWT	200		mg/kg diet	0.110	0.0138	25.1			200			Chang and Stokstad, 1975
p,p'-DDE	Coturnix japonica	13 w	EGWT	200		mg/kg diet	0.112	0.0140	25			200			Davison et al., 1976
p,p'-DDE	Coturnix japonica	13 w	BDWT	200		mg/kg diet	0.112	0.0140	25			200			Davison et al., 1976
DDE	Coturnix japonica	14 w	CRAK	200		mg/kg diet	0.154	0.0172	22.4			200			Chang and Stokstad, 1975
DDE	Coturnix japonica	14 w	ESTH		50	mg/kg diet	0.110	0.0138		6.29			50		Chang and Stokstad, 1975
p,p'-DDMU	Coturnix japonica	21 d	BDWT	250		mg/kg diet	0.118	0.0145	30.7			250			Bunyan and Page, 1973
DDT	Coturnix japonica	3 w	BDWT		0.01	% in diet	0.034	0.0064		18.9			100		DeWitt, 1955
p,p'-DDT	Coturnix japonica	14 d	RSUC		3.6	mg/bird/d	0.100	0.0130		36		< 100	200	✓,4,12	Jones and Summers, 1968
o,p'-DDT	Coturnix coturnix	3 w	TEWT	37.6		mg/kg bw/d	0.114	0.0142	37.6			303			Cooke, 1970
o,p'-DDT	Coturnix coturnix	3 w	BDWT	37.6		mg/kg bw/d	0.114	0.0142	37.6			303			Cooke, 1970
DDT	Coturnix japonica	120 d	HTCH		13.8	mg/kg bw/d	0.100	0.0130		13.8			106		DeWitt, 1955
p,p'-DDT	Coturnix japonica	14 d	BDWT		100	mg/kg diet	0.100	0.0300		13		50	100	✓,1	Sifri et al., 1975
p,p'-DDT	Coturnix japonica	21 d	BDWT	100		mg/kg diet	0.117	0.0144	12.3			100			Bunyan et al., 1972
p,p'-DDT	Coturnix japonica	22 d	BDWT	200		mg/kg diet	0.077	0.0110	28.5			200			Sell et al., 1972
p,p'-DDT	Coturnix japonica	40 d	FTEG	200	400	mg/kg diet	0.100	0.0130	25.7	51.5		200	400		Smith et al., 1969
p,p'-DDT	Coturnix japonica	3 gen	FERT		15	mg/kg diet	0.100	0.0130		1.95		<7.5	15	✓,5	Carnio and McQueen, 1973
DDT - Technical	Coturnix japonica	70 d	CRAK	50	250	mg/kg diet	0.100	0.0130	6.5	32.5		50	250		Grassle and Biessmann, 1982
p,p'-DDT	Coturnix japonica	74 d	NSTI		100	mg/kg diet	0.100	0.0130		13			100		Cecil et al., 1971
p,p'-DDT	Coturnix japonica	168 d	TPRD	100		mg/kg diet	0.121	0.0200	16.4			100			Robson et al., 1976
p,p'-DDT	Coturnix japonica	168 d	BDWT	100		mg/kg diet	0.121	0.0200	16.4			100			Robson et al., 1976
DDT	Coturnix japonica	5 w	BDWT	100		mg/kg diet	0.142	0.0163	11.5			100			Chang and Stokstad, 1975
DDT	Coturnix japonica	5 w	BDWT	200		mg/kg diet	0.181	0.0191	21.1			200			Chang and Stokstad, 1975
DDT	Coturnix japonica	5 w	PROG	5 [f]		mg/kg diet	0.012	0.0033	1.36 [f]			**5**		✓,6	Shellenberger, 1978
DDT - Commercial	Coturnix japonica	10 w	PROG	100		mg/kg diet	0.100	0.0130	12.3			100			Scott et al., 1975
DDT - Commercial	Coturnix japonica	10 w	TPRD	100		mg/kg diet	0.090	0.0121	12.7			100			Scott, 1977
p,p'-DDT	Coturnix japonica	12 w	EGWT	40		mg/kg diet	0.100	0.0130	5.2			40			Davison et al 1976
DDT	Coturnix japonica	14 w	ESTH	50	200	mg/kg diet	0.181	0.0191	5.28	21.1		50	200		Chang and Stokstad, 1975
DDT	Coturnix japonica	14 w	ESTH	100		mg/kg diet	0.142	0.0163	11.5			100			Chang and Stokstad, 1975
p,p'-DDT	Coturnix japonica	16 w	TPRD	10	40	mg/kg diet	0.100	0.0130	1.3	5.2		10	40		Davison et al 1976
DDE	Falco sparverius	14d	ESTH		3	mg/kg diet	0.120	0.0146		0.366			3		Peakall et al., 1973
DDE	Falco sparverius	6 mo	ESTH	0.3	3	mg/kg diet	0.111	0.0139	0.0396	0.396		**0.3**	3	✓	Lincer, 1975
p,p'-DDE	Falco sparverius	1 y	ESTH		10	mg/kg diet	0.111	0.0139		1.24			10		Wiemeyer and Porter, 1970

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
p,p'-DDE	Gallus domesticus	45 d	ESWT	40		mg/kg diet	1.600	0.0790	1.98			40			Lundholm, 1990
p,p'-DDE	Gallus domesticus	28 w	BDWT	25	50	mg/kg diet	1.911	0.1127	1.47	2.95		25	50		Lillie et al., 1972
p,p'-DDE	Gallus domesticus	28 w	EGWT	50		mg/kg diet	1.600	0.0790	2.47			50			Cecil et al. 1972
p,p'-DDE	Gallus domesticus	28 w	FERT	50		mg/kg diet	1.790	0.1084	3.03			50			Lillie et al., 1972
p,p'-DDT	Gallus domesticus	14 d	BDWT		100	mg/kg diet	0.084	0.0116	13.8			<50	100	✓,7,12	Sifri et al., 1975
DDT - Technical	Gallus domesticus	28 d	ESTH	300	600	mg/kg diet	1.600	0.0790	14.5	29		300	600		Britton, 1975
p,p'-DDT	Gallus domesticus	30 d	BDWT	5	50	mg/kg diet	2.037	0.0925	0.227	2.27		5	50		Cecil et al., 1978
DDT	Gallus domesticus	30 d	TPRD	300		mg/kg diet	1.838	0.0865	14.1			300			Waibel et al., 1972
DDT	Gallus domesticus	30 d	BDWT	300		mg/kg diet	1.838	0.0865	14.1			300			Waibel et al., 1972
p,p'-DDT	Gallus domesticus	30 d	TEWT	500		mg/kg diet	1.980	0.0908	22.9			500			Cecil et al., 1978
DDT - Technical	Gallus domesticus	133 d	PRWT		300	mg/kg diet	1.600	0.0790		14.8			300		Britton et al. 1974
DDT	Gallus domesticus	2 mo	ESTH	7.5	10	mg/kg diet	1.600	0.0790	0.37	0.494		7.5	10		Smith et al., 1969
DDT - Technical	Gallus domesticus	2 mo	ESTH		10	mg/kg diet	1.600	0.0790		0.494			10		Cecil et al., 1973
p,p'-DDT	Gallus domesticus	2 mo	ESTH		10	mg/kg diet	1.600	0.0790		0.494			10		Cecil et al., 1973
DDT - Technical	Gallus domesticus	3 w	BDWT		400	mg/kg diet	0.173	0.0186		42.5			400		Silver and Alpern, 1979
p,p'-DDT	Gallus domesticus	6 w	FTEG	15	75	mg/bird/d	1.600	0.0790	9.37	46.9		190	949		Pepperell, 1972
DDT - Commercial	Gallus domesticus	10 w	TPRD	100		mg/kg diet	1.600	0.0790	4.67			100			Scott, 1977
DDT - Commercial	Gallus domesticus	10 w	PROG	100		mg/kg diet	1.600	0.0790	4.67			100			Scott et al., 1975
DDT	Gallus domesticus	10 w	TPRD		0.1	mg/kg diet	1.600	0.0790		4.94		**0.05**	0.1	✓,1	Sauter and Steele, 1972
p,p'-DDT	Gallus domesticus	12 w	NOPN	200		mg/kg diet	1.569	0.0780	9.85			200			Davison and Sell, 1972
p,p'-DDT	Gallus domesticus	12 w	BDWT	200		mg/kg diet	1.569	0.0780	9.85			200			Davison and Sell, 1972
DDT - Technical	Gallus domesticus	24 w	TEDG		12.5	mg/kg bw/d	1.300	0.0690		12.5			235		Balasubramaniam and Sundararaj 1993
o,p'-DDT	Gallus domesticus	28 w	EGWT	50		mg/kg diet	1.600	0.0790	2.47			50			Cecil et al. 1972
o,p'-DDT	Gallus domesticus	28 w	FERT	50		mg/kg diet	1.893	0.1133	2.99			50			Lillie et al., 1972
o,p'-DDT	Gallus domesticus	28 w	BDWT	50		mg/kg diet	1.893	0.1133	2.99			50			Lillie et al., 1972
p,p'-DDT	Gallus domesticus	28 w	EGWT	50		mg/kg diet	1.600	0.0790	2.47			50			Cecil et al. 1972
p,p'-DDT	Gallus domesticus	28 w	TPRD	50		mg/kg diet	2.153	0.1180	2.74			50			Lillie et al., 1973
p,p'-DDT	Gallus domesticus	28 w	FERT	50		mg/kg diet	1.884	0.1135	3.01			50			Lillie et al., 1972
p,p'-DDT	Gallus domesticus	28 w	BDWT	50		mg/kg diet	1.884	0.1135	3.01			50			Lillie et al., 1972
p,p'-DDT	Gallus domesticus	32 w	GREP	100		mg/kg diet	2.210	0.0680	3.08			100			Arscott et al 1972
p,p'-DDT	Gallus domesticus	32 w	BDWT		100	mg/kg diet	2.210	0.0680		3.08			100		Arscott et al 1972
DDT - Pure isomers	Gallus domesticus	40 w	BDWT	10	50	mg/kg diet	2.187	0.1220	0.558	2.79		10	50		Lillie et al., 1973
DDT - Pure isomers	Gallus domesticus	40 w	FERT	50		mg/kg diet	2.121	0.1190	2.72			50			Lillie et al., 1973
DDT - Technical	Gallus domesticus	40 w	FERT	50		mg/kg diet	2.204	0.1200	1.93			50			Lillie et al., 1973
DDT - Technical	Gallus domesticus	40 w	FERT	50		mg/kg diet	2.078	0.1140	2.74			50			Lillie et al., 1973
DDT - Technical	Gallus domesticus	40 w	BDWT	50		mg/kg diet	2.204	0.1200	1.93			50			Lillie et al., 1973
DDT - Technical	Gallus domesticus	40 w	BDWT		10	mg/kg diet	1.976	0.1170		0.592			10		Lillie et al., 1973
DDT	Gallus domesticus	47 w	SPCV	25	37.5	mg/kg bw/d	1.300	0.0690	25	37.5		471	706		George and Sundararaj 1995
DDT and DDE Mixture	Gallus domesticus	18 d	ESQU	40		mg/kg diet	1.600	0.0790	1.94			40			Stephen et al, 1971
p,p'-DDT - Technical	Haliaeetus leucocephalus	23 d	TEDG		160	mg/kg diet	5.350	0.1734		5.19			160		Locke et al, 1966
p,p'-DDT - Technical	Haliaeetus leucocephalus	55 d	BDWT		10	mg/kg diet	5.625	0.4010		0.713		**< 10**	10	2	Chura and Stewart 1967

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL $[mg/kg_{bw}.d]$	LOAEL $[mg/kg_{bw}.d]$		NOAEC $[mg/kg_{fd}]$	LOAEC $[mg/kg_{fd}]$		
p,p'-DDT - Technical	Haliaeetus leucocephalus	120 d	SPCL	10		mg/kg diet	5.350	0.1734	0.324			10			Locke et al, 1966
p,p'-DDE	Lonchura striata	6 w	PROG		34	ug/bird/d	0.014	0.0036		2.41		< 9	**9**	2	Jefferies 1971
p,p'-DDT	Lonchura striata	6 w	PROG		34	ug/bird/d	0.014	0.0036		2.41		< 9	**9**	2	Jefferies 1971
o,p'-DDT	Meleagris gallopavo	15 w	RHIS	265		mg/kg diet	14.300	0.3289	6.09			265			Simpson et al., 1972
p,p'-DDT	Meleagris gallopavo	15 w	RHIS	265		mg/kg diet	14.300	0.3289	6.09			265			Simpson et al., 1972
DDE	Otus asio	20 mo	ESTH	2.8		mg/kg diet	0.194	0.0200				2.8		✓,8	McLane and Hall, 1972
DDT - Mixture	Pelecanus erythrorhynchos	10 w	BDWT	72		mg/kg diet	4.810	0.6950	10.9			**72**		✓,9	Greichus et al, 1975
DDT + metabolites	Phalacrocorax auritus	9 w	BDWT	25		mg/kg diet	2.200	0.0972	1.1			**25**			Greichus and Hannon, 1973
DDT	Phasianus colchicus	74 d	BDWT		5.72	mg/bird/d	0.950	0.0563		6.02			100	10	Genelly and Rudd, 1955
DDT	Phasianus colchicus	90 d	BDWT	600		mg/kg diet	0.950	0.0563	35.6			600			Genelly and Rudd, 1955
DDT - Technical	Phasianus colchicus	105 d	PROG	5.1	6.86	mg/kg bw/d	1.300	0.0690	4.51	6.07		96	129		Azevedo et al., 1965
DDT	Phasianus colchicus	10 w	DEYO		5.72	mg/bird/d	0.950	0.0572		6.02			100		Genelly and Rudd, 1956
DDT	Phasianus colchicus	10 w	BDWT		5.72	mg/bird/d	0.950	0.0572		6.02			100		Genelly and Rudd, 1956
p,p'-DDE	Phasianus colchicus	11 w	ESTH	10		mg/kg diet	0.950	0.0563	0.592			**10**		✓	Haseltine et al., 1974
DDE	Streptopelia risoria	14 d	ESTH		10	mg/kg diet	0.149	0.0169		1.13			10		Peakall et al., 1973
p,p'-DDT	Streptopelia risoria	29 d	OEGP		10	mg/kg diet	0.146	0.0166		1.14			10		Peakall, 1970
p,p'-DDE	Streptopelia risoria	63 d	COUR		10	mg/kg diet	0.152	0.0171		1.12			10		Haegele and Hudson 1977
p,p'-DDE	Streptopelia risoria	90 d	GREP		10	mg/kg diet	0.144	0.0165		1.14		5	10	✓,1,11	Richie and Peterle, 1979
p,p'-DDE	Streptopelia risoria	126 d	PROG		40	mg/kg diet	0.144	0.0165		4.58		< 20	40	✓,12	Haegele and Hudson, 1973
p,p'-DDE	Streptopelia risoria	3 w	ESTH		40	mg/kg diet	0.144	0.0165		4.57		20	40	✓,1	Haseltine et al., 1974
DDE	Tyto alba	1 y	PROG		2.83	mg/kg diet	0.568	0.0403		0.211		**< 1.5**	3	✓,12	Mendenhall et al., 1983
p,p'-DDE	Zonotrichia albicollis	6 w	BDWT	25		mg/kg diet	0.026	0.0054	5.21			25			Mahoney 1975
DDT - Technical	Zonotrichia albicollis	6 w	BDWT		5	mg/kg diet	0.026	0.0054		1.04		**< 5**	5	2	Mahoney 1975

Notes

a: BDWT = bodyweight; COUR = courtship behaviour; CRAK = eggshell cracking; DEYO = death young; EGWT = egg weight; ESIN = eggshell index; ESQU = eggshell quality; ESTH = eggshell thinning; ESWT = eggshell weight; FERT = fertility; FTEG = fertile egg; GEGG = general egg effect; GREP = general reproduction; HTCH = hatching; NOPN = number of organisms per nest; NSTI = nest initiation; OEGP = onset of egg production; PROG = progeny counts; PRWT = progeny weight; RHIS = reproductive histology; RSUC = reproductive success; SPCL = sperm cell counts; SPCV = sperm counts; TEDG = testes degeneration; TEWT = testes weight; TPRD = total production.

b: ✓ = full reference or abstract checked

1: <20% effect, NOAEL or NOAEC = LOAEL/2 or NOAEC/2

2: effect level unknown (reference/abstract not available), NOAEC/L cannot be extrapolated from reported LOAEL and is presented as a <-value

3: no effects observed at single dose tested, NOAEL/NOAEC presented as ≥-value

4: dietary concentration reported as 200 mg/kg fd; dose as 28 and 22 mg/bird per week

5: exposure duration given as 50 d in [24], but study involves 3 generations; no effect at 15 mg/kg fd in 1st generation, but significant effect in 2nd and 3rd generation; >20% reduction in egg production

and fertility
6: 5 mg/kg fd indicated as LOAEL in [24], but study abstract indicates that only slight effects occurred at the next higher dose of 50 mg/kg fd, so NOAEL is set to 5
7: result reported as NOAEL 100 µg/g diet in [24]; significant increase of chick weight by >30%, 80% increase in sleeping time, LOAEC is 100 mg/kg fd, NOAEC < 50 (see note 10)
8: study result given as LOAEL 2.8 mg/kgbw d in [24], result should be NOAEL 2.8 mg/kg fd. See also Table A2.1.
9: NOAEL mistakenly reported as 72 mg/kg bw.d in [24], correct NOAEL is 72 mg/kg fd and 10.9 mg/kg bw.d
10: a 1000 times lower food ingestion rate is given in [24], which seems to be incorrect in view of the other data on Phasianus colchicus from the same study.
11: reference checked: DDE at 10 mg/kg fd caused delay in oviposition from 12.5 to 15.5 days (0.047 ≤ P 0.066)
12: study/abstract checked: effect level >20%, NOAEL or NOAEC = < LOAEL/2 or < NOAEC/2

Appendix 3. Toxicity of DDT and metabolites to mammals

Table A3.1 Toxicity of DDT to mammals as reported by Jongbloed et al. [32]. Data indicated with "up" are additional to those cited by Romijn et al. [20]. Values are reported in mg/kg feed. Conversions are made considering exposure duration and magnitude of effects, see copy of original footnotes. Note that instead of footnote 1, most likely footnote (2) is applicable to the value for Microtus pennsylvanicus; Klepinger et al. (1970) should read Keplinger et al. (1970)

DDT (total)

LC50	Blerina brevicaudus	17 days	651		651		Blus (1978)	up
NOEC re	Rattus norvegicus	7 months	20		20		Clement and Okey (1974)	
re	Mus musculus	6 generations	25		25		Klepinger et al. (1970)	
mo	Saimura sciureus	6 months	5	(3)	28.4		Cranmer et al. (1972)	
mo	Microtus pennsylvanicus	31 days	1000		100	(1)	Coburn and Treichler (1946)	
mo,gr	Macaca mulatta	7.5 years	200		200		Durham et al. (1963)	
mo	Canis domesticus	4 years	400		400		Lehman (1965)	

LEGENDS

LC50= (sub)acute mortality, NOEC= no observed effect concentration (effect recorded is specified).
mo=mortality, re=reproduction, gr=growth.
up=update, ra=raptorial species, se=selected NOEC for derivation of a bird NOEC.
WE=Weasel, BG=Badger

(1) NOEC value derived by applying a factor 2 on the lowest concentration tested, which caused <20% effect relative to the control group, or a factor 3 on the lowest concentration which caused 20−50% effect relative to the control group.

(2) NOEC derived by applying a factor 10 on the value obtained from the literature to compensate for the uncertainty in establishing a (chronic) NOEC from short time (<1 month) studies

(3) value reported in the literature in mg/kg body weight. These values were converted into a mg/kg food value with a body weight/daily food intake factor: 40 for Canis domesticus, 33.3 for Oryctolagus cuniculus, 20 for Macaca spec. and Rattus norvegicus, 8.3 for Microtus spec. and Mus musculus, and 5.7 for Saimura sciureus.

(4) reported value was not compensated for the relative contribution of the CH3Hg group to the molecular weight of the compound with which the study was carried out.

(5) Contaminant concentration have to be expresed on a WW−basis. For concentrations on DW basis a factor is applied depending on the dry matter percentage of the food.

Table A3.2 Effects of DDT, DDD and DDE on reproduction and growth of mammals as reported in the Eco-SSL report of the US EPA [24]. No or Lowest Adverse Effect Levels (NOAEL/LOAEL) expressed as dietary dose [mg/kg$_{bw}$ d] are calculated in the Eco-SSL report if study results is reported as dietary concentration [mg/kg$_{diet}$], based on reported or default data on body weight and food ingestion. Shaded columns: when original study results were expressed as daily dose, No or Lowest Observed Adverse Effect Concentrations (NOAEC/LOAEC) expressed as dietary concentration [mg/kg$_{fd}$] were recalculated for the present report using data on body weight and food ingestion. Lowest relevant endpoint per species indicated in bold for dietary concentration. See notes for comments on study results.

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
DDT-technical	Canis familiaris	3 gen.	FERT		1	mg/kg bw/d	10.45	0.4728		1		**11**	22	✓,1,2	Ottoboni et al., 1977
p,p'-DDE	Mesocricetus auratus	72 w	BDWT	500	1000	mg/kg diet	0.14	0.0136	48.3	96.5		**500**	1000	✓	Rossi et al., 1983
DDT-technical	Mesocricetus auratus	72 w	BDWT	1000		mg/kg diet	0.13	0.0154	98.8			1000		✓	Rossi et al., 1983
DDT-technical	Mus musculus	120 d	FERT	7		mg/kg diet	0.0222	0.0030	0.731			**≥ 7**		✓,3	Ware and Good, 1967
DDT-technical	Mus musculus	120 d	FERT		7	mg/kg diet	0.0222	0.0030	0.731				7	✓,3	Ware and Good, 1967
DDT-technical	Mus musculus	86 d	PRWT		5	mg/kg diet	0.0288	0.0037		0.636			5	✓,4	Ledoux et al., 1977
DDT-technical	Mus musculus	84 d	PRWT	40		mg/kg diet	0.0288	0.0037	5.09			40		✓	Ledoux et al., 1977
DDT-technical	Mus musculus	15 d	PROG		30	mg/kg bw/d	0.0288	0.0037		3.82			232	✓	Ledoux et al., 1977
p,p'-DDT	Mus musculus	28 d	TEWT	0.25		mg/org/d	0.0375	0.0046	6.67			54			Orberg and Lundberg, 1974
p,p'-DDT	Mus musculus	260 d	PRWT	100		mg/kg diet	0.0346	0.0043	12.4			100			Deichmann, 1974
DDT-technical	Mus musculus	50 d	RSUC	200	300	mg/kg diet	0.0288	0.0037	25.8	38.8		200	300		Bernard and Gaertner, 1964
DDT-technical	Mus musculus	10 d	TEWT	50		mg/kg bw/d	0.04	0.0049	50			410			Thomas, 1974
DDT	Mus musculus	55 d	TEWT	300		mg/kg diet	0.0247	0.0050	60.7			300			Cannon and Holcombe
p,p'-DDT	Mus musculus	6 mo	PRWT		0.7	mg/kg bw/d	0.0325	0.0041		0.7		< 6	6	X	Tarjan and Kemeny, 1969
DDT-technical	Mus musculus	6 w	PROG		200	mg/kg diet	0.0325	0.0041		25.3			200		Craig and Ogilvie, 1974
p,p'-DDT	Mus musculus	260 d	BDWT	100		mg/kg diet	0.0346	0.0043	12.4			100			Deichmann, 1974
DDT	Mus musculus	55 d	BDWT	300		mg/kg diet	0.0247	0.0050	60.7			300			Cannon and Holcombe, 1968
DDT-technical	Oryctolagus cuniculus	116 d	PROG	1.3		mg/kg bw/d	4.5	0.2365	1.3			**25**		✓	Seiler et al., 1994
DDT-technical	Oryctolagus cuniculus	12 w	OVRT		3	mg/kg bw/d	4.5	0.2365		3			57		Lindenau et al.,1994
p,p'-DDT	Oryctolagus cuniculus	57 d	BDWT	6.54		mg/kg bw/d	3.07	0.1727	6.54			116			Street and Sharma, 1975
o,p'-DDT	Ovis aries	9 mo	GREP	10		mg/kg diet	32	1.1863	0.371			**10**		X	Wrenn et al., 1971
DDT	Ovis aries	17 w	GREP	0.2		g/org/d	70	1.1000	2.57			182			Cecil et al., 1975
DDT	Ovis aries	175 d	PRWT		106	mg/kg diet	68.56	2.7300		4.22			106		Wilson et al., 1946
DDT	Ovis aries	94 d	BDWT	62		mg/kg diet	48.32	1.3600		1.75		62			Wilson et al., 1946
DDT	Peromyscus polionotus	15 mo	PROG	2.4		mg/kg bw/d	0.0151	0.0020	2.4			**18**		✓	Wolfe et al, 1979
DDA	Rattus norvegicus	6 w	BDWT	200		mg/kg diet	0.1345	0.0132	19.6			200			Banerjee and Pasha,

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
															1996
DDD	Rattus norvegicus	43 d	BDWT	200		mg/kg diet	0.258	0.0226	17.5			200			Foster, 1968
p,p'-DDD	Rattus norvegicus	6 w	BDWT	200		mg/kg diet	0.1427	0.0139	19.4			200			Banerjee and Pasha, 1996
p,p'-DDE	Rattus norvegicus	5 d	OTHR	10	100	mg/kg bw/d	0.35	0.0276	9.9	99		127	1267	✓,5	You et al., 1999
p,p'-DDE	Rattus norvegicus	5 d	ODVP	10	50	mg/kg bw/d	0.4	0.0323	10	50		124	618		Loeffler and Peterson, 1999
p,p'-DDE	Rattus norvegicus	5 d	RHIS	100		mg/kg bw/d	0.248	0.0218	99			1136			Leavens et al., 2002
p,p'-DDE	Rattus norvegicus	75 d	BDWT	7.14		mg/kg bw d	0.32	0.0269	7.07			85			Kornbrust et al., 1986
p,p'-DDE	Rattus norvegicus	21 d	BDWT	150		mg/kg diet	0.218	0.0216	13.5			150			Bunyan and Page, 1973
p,p'-DDE	Rattus norvegicus	21 d	BDWT	150		mg/kg diet	0.206	0.0187	13.7			150			Bunyan et al. 1972
p,p'-DDE	Rattus norvegicus	6 w	BDWT	200		mg/kg diet	0.1388	0.0135	19.5			200			Banerjee and Pasha, 1996
p,p'-DDMU	Rattus norvegicus	21 d	BDWT	150		mg/kg diet	0.216	0.0195	13.5			150			Bunyan and Page, 1973
o,p'-DDT	Rattus norvegicus	168 d	ORWT	1	2.5	mg/kg diet	0.072	0.0079	0.11	0.274		1	2.5	✓	Wrenn et al., 1970
DDT	Rattus norvegicus	18 mo	BDWT	10		mg/kg bw d	0.3419	0.0300		7.5			114		Ali and Shakoori, 1996
DDT	Rattus norvegicus	9 d	BDWT	20		mg/kg bw d	0.1677	0.0300		15			112		Ali and Shakoori, 1996
p,p'-DDT	Rattus norvegicus	6 w	BDWT	200		mg/kg diet	0.142	0.0138	19.4			200			Banerjee and Pasha, 1996
DDT-technical	Rattus norvegicus	1 yr	BDWT	20		mg/kg diet	0.243	0.0215	1.77			20			Banerjee et al., 1983
p,p'-DDT	Rattus norvegicus	21 d	BDWT	150		mg/kg diet	0.211	0.0191	13.6			150			Bunyan et al., 1972
o,p'-DDT	Rattus norvegicus	7 d	GREP	100	250	mg/kg diet	0.0689	0.0053	7.62	19		100	250		Cecil et al., 1971
o,p'-DDT	Rattus norvegicus	7 d	BDWT	1000		mg/kg diet	0.0689	0.0053	76.2			1000			Cecil et al., 1971
DDT-technical	Rattus norvegicus	120	BDWT		0.2	mg/kg bw d	0.3243	0.0272		0.2		< 1 [d]	2	✓,6	Chowdhury et al., 1990
p,p'-DDT	Rattus norvegicus	8 mo	PRWT	20	200	mg/kg diet	0.297	0.0253	1.71	17.1		20	200	✓	Clement and Okey, 1974
o,p'-DDT	Rattus norvegicus	8 mo	PRWT	200	1000	mg/kg diet	0.297	0.0253	17.1	85.3		200	1000	✓	Clement and Okey, 1974
o,p'-DDT	Rattus norvegicus	7 d	PVOP [c]	500	1000	mg/kg diet	0.156	0.0149	47.8	95.6		500	1000		Clement and Okey, 1972
p,p'-DDT	Rattus norvegicus	72 d	BDWT	20		mg/kg diet	0.2602	0.0165	1.27			20		X	Dinu et al., 1974
DDT-technical	Rattus norvegicus	72 d	BDWT	20		mg/kg diet	0.1905	0.0135	1.42			20		X	Dinu et al., 1974
DDT	Rattus norvegicus	72 d	BDWT	20		mg/kg diet	0.1859	0.0139	1.5			20		X	Dinu et al., 1974
DDT-technical	Rattus norvegicus	89 w	ABNM [c]		200	mg/kg diet	0.4	0.0323		16.2			200		Fitzhugh and Nelson, 1947
DDT-technical	Rattus norvegicus	12 w	BDWT	200	400	mg/kg diet	0.2037	0.0186	16.9	33.7		200	400		Fitzhugh and nelson, 1947
DDT-technical	Rattus norvegicus	42 d	BDWT	200		mg/kg diet	0.247	0.0218	17.6			200			Foster, 1968
DDT-technical	Rattus norvegicus	116 d	DEYO	32.4		mg/kg bw/d	0.2024	0.0133	32.2			493			Hayes, 1976
DDT-technical	Rattus norvegicus	14 d	BDWT	1024	1550	mg/kg diet	0.12	0.0120	90.3	137		1024	1550		Hoffman et al., 1970
DDT-technical	Rattus norvegicus	36 w	PROG		75	mg/kg diet	0.25	0.0220		6.6			75		Jonsson et al., 1976

Chemical	Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
									NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
DDT-technical	Rattus norvegicus	8 w	BDWT	26.5		mg/kg bw d	0.578	0.0438	26.5			350			Kimbrough et al., 1971
p,p'-DDT	Rattus norvegicus	75 d	GSTT	7.14		mg/kg bw/d	0.32	0.0269	7.07			85			Kornbrust et al, 1986
DDT	Rattus norvegicus	14 d	TEWT		200	mg/kg bw/d	0.032	0.0041		200			1578		Krause et al., 1975
DDT	Rattus norvegicus	14 d	BDWT	200		mg/kg bw d	0.032	0.0041	200			1578			Krause et al., 1975
DDT-commercial	Rattus norvegicus	6 mo	BDWT		800	mg/kg diet	0.4702	0.0369		62.9			800		Laug and Fitzhugh, 1946
DDT-commercial	Rattus norvegicus	4 mo	GREP		0.02	mg/kg bw/d	0.3846	0.0313		0.02		< 0.25	0.25	X,7	Naishtein and Leibovich, 1970
DDT-commercial	Rattus norvegicus	8 w	FERT		2	mg/kg bw/d	0.204	0.0186		2			22		Nickerson and Sniffen, 1973
DDT-commercial	Rattus norvegicus	5 w	BDWT	2		mg/kg bw/d	0.204	0.0186	2			22			Nickerson and Sniffen, 1973
DDT-technical	Rattus norvegicus	117 d	RSUC	200		mg/kg diet	0.267	0.0233	17.2			200			Ottoboni, 1969
DDT-technical	Rattus norvegicus	23 mo	PROG	20		mg/kg diet	0.338	0.0282	1.65			20			Ottoboni, 1972
DDT-technical	Rattus norvegicus	14 d	RBEH		50	mg/kg diet	0.25	0.0100		2			50		Paulsen et al., 1975
DDT	Rattus norvegicus	14 d	BDWT	0.1		% in diet	0.2	0.0183	96.3			1000			Platt and Cockrill, 1969
DDT-technical	Rattus norvegicus	8 w	TEWT		2	mg/kg bw/d	0.25	0.0220		1			23		Rao et al., 1978
DDT-technical	Rattus norvegicus	20 w	BDWT	300		mg/kg diet	0.3751	0.0307	22.6			300			Treon et al., 1951
p,p'-DDT	Rattus norvegicus	28 w	BDWT	25		mg/kg diet	0.3738	0.0306	2.04			25			Treon et al., 1953
DDT	Rattus norvegicus	120 d	FERT	25		mg/kg diet	0.2024	0.0185	2.28			25			Treon et al., 1954
DDT	Rattus norvegicus	6 w	BDWT	15	44	mg/L	0.16	0.0152	1.43	4.19					Wilson et al., 1946
o,p'-DDT	Rattus norvegicus	15 d	GREP	10	50	ug/org/d	0.072	0.0079	0.139	0.694		1.3	6.3	✓	Wrenn et al., 1970
o,p'-DDT	Rattus norvegicus	15 d	GREP	10	50	ug/org/d	0.0683	0.0075 [f]	0.147	0.735		1.3	6.6	✓	Wrenn et al., 1970
o,p'-DDT	Rattus norvegicus	15 d	BDWT	50		ug/org/d	0.072	0.0079	0.694			6.3		✓	Wrenn et al., 1970
p,p'-DDT	Rattus norvegicus	15 d	BDWT	50		ug/org/d	0.0683	0.0075 [f]	0.735			6.6		✓	Wrenn et al., 1970
o,p'-DDT	Rattus norvegicus	17 w	GREP	10	20	mg/kg diet	0.228	0.0204	0.894	1.79		10	20	✓	Wrenn et al., 1971
p,p'-DDT	Rattus norvegicus	50 d	BDWT	583		mg/kg diet	0.3918	0.0318		47.3			583		Yagi et al., 1979

Notes

a: ABNM = abnormality, in this case most likely associated with ovary; BDWT = bodyweight; DEYO = death young; GREP = general reproduction; GSTT = gestation time; ODVP = organ development time; ORWT = organ weight changes, in this case ovary weight; OTHR = other, exact endpoint cannot be deduced from reference; OVRT = ovulation rate; PROG = progeny counts; PRWT = progeny weight; PVOP = not explained in the Eco-SSL report and cannot be decuced from the (abstract) of the reference; RBEH = reproductive behaviour; RHIS = reproductive histology; RSUC = reproductive success; TEWT = testes weight

b: ✓ = full reference or abstract checked; X = reference or abstract not available

1: result presented as LOAEL 10 mg/kg bw.d in [24], however, original reference indicates that significant <20% effect on age at puberty of F2 was found at lowest dose of 1 mg/kg bw.d. Trend present in all generations.

2: <20% effect, NOAEL or NOAEC = LOAEL/2 or NOAEC/2

3: Eco-SSL report lists the same study twice, result #108 with NOAEL of 7 mg/kg fd, result #136 with LOAEL of 7 mg/kg fd. Based on abstract, differences may refer to different strains. Level of effect cannot be checked

4: exposure time given as 15 d in [24], but feeding lasted for 86 d and weight was determined for 15-days old F1 pups; results of different experiments not consistent, effect of 5 mg/kg fd in 1st experiment not observed in other experiments with higher dose levels (see next line); LOAEL not further considered for risk limit derivation

5: endpoint not clear

6: effect level >20%, NOAEL or NOAEC = < LOAEL/2 or < NOAEC/2

7: effect level unknown (reference/abstract not available), NOAEC cannot be extrapolated from LOAEL and is presented as a <-value

8: a 10 times higher food ingestion rate is given in [24], which seems to be incorrect in view of the other data on Rattus norvegicus from the same study.

Appendix 4. Toxicity of drins to bird

Table A4.1 Toxicity of aldrin to birds as reported by Van de Plassche et al. [22].

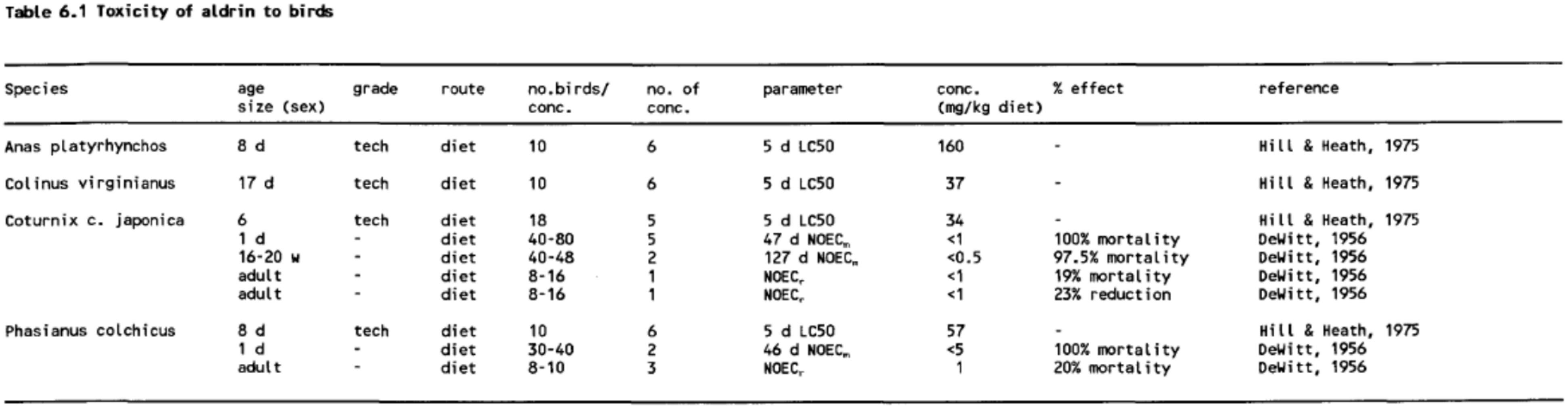


Table 6.1 Toxicity of aldrin to birds

Species	age size (sex)	grade	route	no.birds/ conc.	no. of conc.	parameter	conc. (mg/kg diet)	% effect	reference
Anas platyrhynchos	8 d	tech	diet	10	6	5 d LC50	160	-	Hill & Heath, 1975
Colinus virginianus	17 d	tech	diet	10	6	5 d LC50	37	-	Hill & Heath, 1975
Coturnix c. japonica	6	tech	diet	18	5	5 d LC50	34	-	Hill & Heath, 1975
	1 d	-	diet	40-80	5	47 d $NOEC_m$	<1	100% mortality	DeWitt, 1956
	16-20 w	-	diet	40-48	2	127 d $NOEC_m$	<0.5	97.5% mortality	DeWitt, 1956
	adult	-	diet	8-16	1	$NOEC_r$	<1	19% mortality	DeWitt, 1956
	adult	-	diet	8-16	1	$NOEC_r$	<1	23% reduction	DeWitt, 1956
Phasianus colchicus	8 d	tech	diet	10	6	5 d LC50	57	-	Hill & Heath, 1975
	1 d	-	diet	30-40	2	46 d $NOEC_m$	<5	100% mortality	DeWitt, 1956
	adult	-	diet	8-10	3	$NOEC_r$	1	20% mortality	DeWitt, 1956

Table A4.2 Toxicity of endrin to birds as reported Van de Plassche et al. [22].

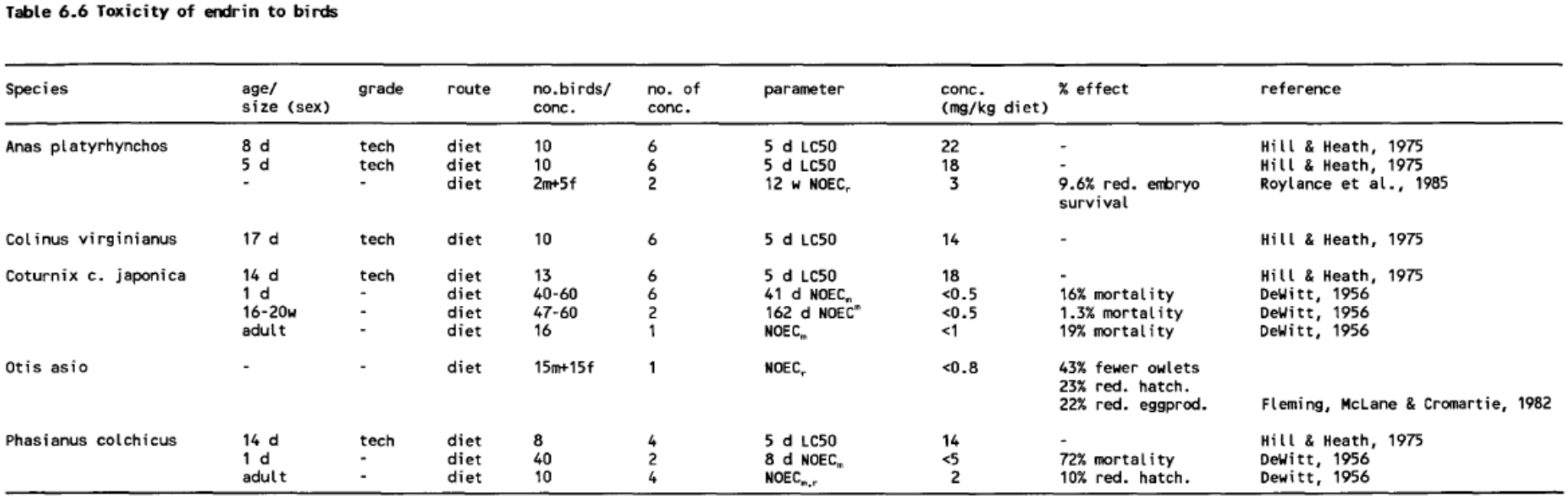
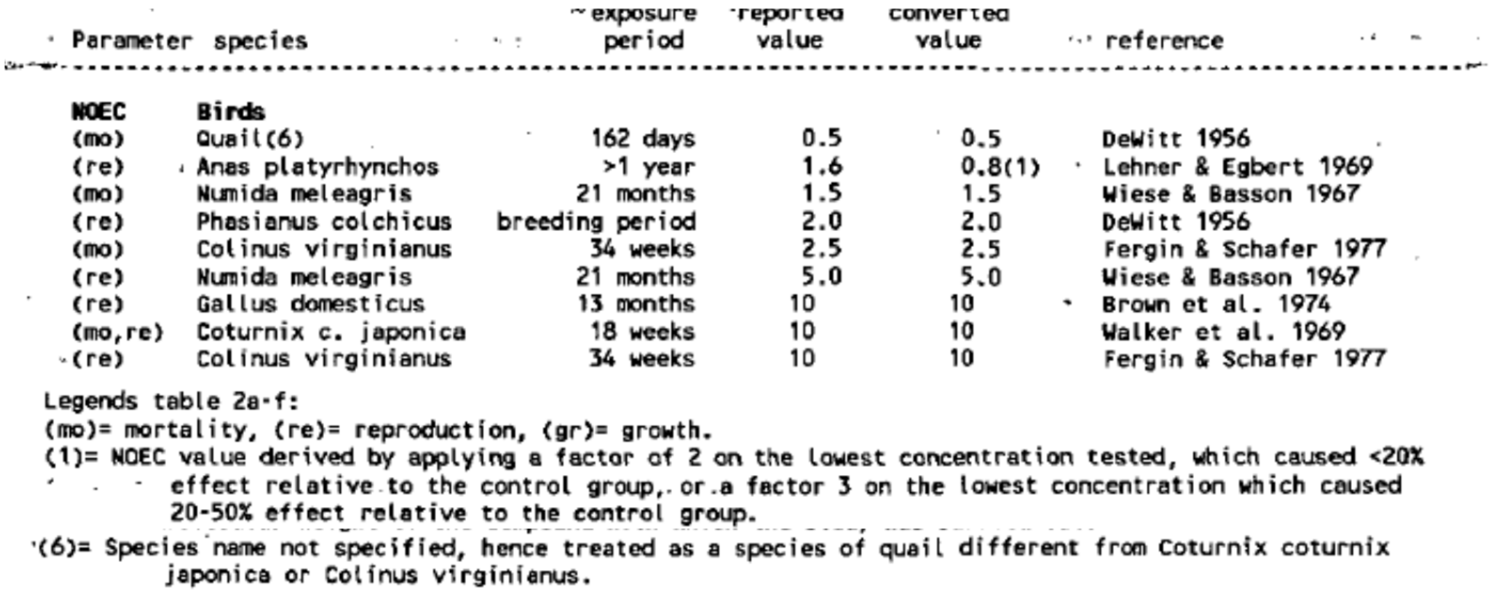


Table 6.6 Toxicity of endrin to birds

Species	age/ size (sex)	grade	route	no.birds/ conc.	no. of conc.	parameter	conc. (mg/kg diet)	% effect	reference
Anas platyrhynchos	8 d	tech	diet	10	6	5 d LC50	22	-	Hill & Heath, 1975
	5 d	tech	diet	10	6	5 d LC50	18	-	Hill & Heath, 1975
	-	-	diet	2m+5f	2	12 w $NOEC_r$	3	9.6% red. embryo survival	Roylance et al., 1985
Colinus virginianus	17 d	tech	diet	10	6	5 d LC50	14	-	Hill & Heath, 1975
Coturnix c. japonica	14 d	tech	diet	13	6	5 d LC50	18	-	Hill & Heath, 1975
	1 d	-	diet	40-60	6	41 d $NOEC_m$	<0.5	16% mortality	DeWitt, 1956
	16-20w	-	diet	47-60	2	162 d $NOEC^m$	<0.5	1.3% mortality	DeWitt, 1956
	adult	-	diet	16	1	$NOEC_m$	<1	19% mortality	DeWitt, 1956
Otis asio	-	-	diet	15m+15f	1	$NOEC_r$	<0.8	43% fewer owlets 23% red. hatch. 22% red. eggprod.	Fleming, McLane & Cromartie, 1982
Phasianus colchicus	14 d	tech	diet	8	4	5 d LC50	14	-	Hill & Heath, 1975
	1 d	-	diet	40	2	8 d $NOEC_m$	<5	72% mortality	DeWitt, 1956
	adult	-	diet	10	4	$NOEC_{m,r}$	2	10% red. hatch.	Dewitt, 1956

Table A4.3 Toxicity of dieldrin to birds as reported by Romijn et al. [20]. Values are presented in mg/kg$_{fd}$.



Parameter	species	exposure period	reported value	converted value	reference
NOEC	**Birds**				
(mo)	Quail(6)	162 days	0.5	0.5	DeWitt 1956
(re)	Anas platyrhynchos	>1 year	1.6	0.8(1)	Lehner & Egbert 1969
(mo)	Numida meleagris	21 months	1.5	1.5	Wiese & Basson 1967
(re)	Phasianus colchicus	breeding period	2.0	2.0	DeWitt 1956
(mo)	Colinus virginianus	34 weeks	2.5	2.5	Fergin & Schafer 1977
(re)	Numida meleagris	21 months	5.0	5.0	Wiese & Basson 1967
(re)	Gallus domesticus	13 months	10	10	Brown et al. 1974
(mo,re)	Coturnix c. japonica	18 weeks	10	10	Walker et al. 1969
(re)	Colinus virginianus	34 weeks	10	10	Fergin & Schafer 1977

Legends table 2a-f:
(mo)= mortality, (re)= reproduction, (gr)= growth.
(1)= NOEC value derived by applying a factor of 2 on the lowest concentration tested, which caused <20% effect relative to the control group, or a factor 3 on the lowest concentration which caused 20-50% effect relative to the control group.
(6)= Species name not specified, hence treated as a species of quail different from Coturnix coturnix japonica or Colinus virginianus.

Note that Quail tested by DeWitt (1956) is considered as *Coturnix japonica* in [22], see Table A41 and A4.2

Table A4.4 Effects of dieldrin on mortality, growth and reproduction of birds as reported in the Eco-SSL report of the US EPA [52]. No or Lowest Adverse Effect Levels (NOAEL/LOAEL) expressed as dietary dose [mg/kg$_{bw}$ d] are calculated in the Eco-SSL report if study results is reported as dietary concentration [mg/kg$_{diet}$], based on reported or default data on body weight and food ingestion. Shaded columns: when original study results were expressed as daily dose, No or Lowest Observed Adverse Effect Concentrations (NOAEC/LOAEC) expressed as dietary concentration [mg/kg$_{fd}$] were recalculated for the present report using data on body weight and food ingestion. See notes for comments on study results.

Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [52]			(no) effect level as dietary concentration		Notes[b]	Ref
								NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
Anas platyrhynchos	24 d	MORT	0.3	16.4	mg/kg diet	0.334	0.075	0.071	3.78		0.3	16.4		Nebeker et al., 1992
Anas platyrhynchos	24 d	BDWT	0.3	16.4	mg/kg diet	0.334	0.075	0.071	3.78		0.3	16.4		Nebeker et al., 1992
Anas platyrhynchos	48 w	SURV	5	10	mg/kg diet	1.1	0.0619	0.28	0.56		5	10		Davison and Sell, 1974
Anas platyrhynchos	48 w	SURV	5	10	mg/kg diet	1.33	0.588	2.21	4.42		5	10		Davison and Sell, 1974
Anas platyrhynchos	48 w	EGPN	10		mg/kg diet	1.1	0.0619	0.563			10			Davison and Sell, 1974
Anas platyrhynchos	48 w	TPRD	10		mg/kg diet	1.33	0.588	4.42			10			Davison and Sell, 1974
Anas platyrhynchos	491 d	MORT		10	mg/kg diet	1.2	0.0655		0.55			10		Lehner and Egbert, 1969
Anas platyrhynchos	42 d	ESTH		1.6	mg/kg diet	0.46	0.0351		0.122		1.6		✓,1	Lehner and Egbert, 1969
Anas platyrhynchos	90 d	RSUC		4	mg/kg diet	1.1	0.0619		0.226			4		Muller and Lockman, 1972
Colinus virginianus	34 w	TPRD	40		mg/kg diet	0.17	0.0184	4.32			40			Fergin and Schafer, 1977
Colinus virginianus	34 w	MORT	2.5	5	mg/kg diet	0.17	0.0184	0.27	0.54		2.5	5	✓,2	Fergin and Schafer, 1977
Colinus virginianus	42 d	MORT	100	200	ug/org	0.16	0.0177	0.625	1.25					Gesell et al., 1979
Columba livia	8 w	MORT	2	4	mg/kg bw/d	0.397	0.0319	2	4		25	50		Jefferies and French, 1972
Coturnix japonica	20 d	PROG		20	mg/kg diet	0.1	0.013		2.6			20		Andujar et al., 1978
Coturnix japonica	14 d	BDWT	15	75	mg/kg diet	0.09	0.0121	2.02	10.1		15	75		Call and Call, 1974
Coturnix japonica	14 d	TPRD		5	mg/kg diet	0.09	0.0121		0.674			5		Call and Call, 1974
Coturnix japonica	14 d	MORT	75		mg/kg diet	0.09	0.0121		10.1		75			Call and Call, 1974
Coturnix japonica	21 d	TPRD		3.1	mg/kg diet	0.1	0.013		0.403			3.1		Call and Harrell, 1974
Coturnix japonica	35 d	BDWT	0.65		mg/kg bw/d	0.103	0.0938	0.65			≥ 0.71		3	Gillett and Arscott, 1969
Coturnix japonica	35 d	MORT	0.65		mg/kg bw/d	0.103	0.0938	0.65			≥ 0.71		3	Gillett and Arscott, 1969
Coturnix japonica	75 d	ESTH	9		mg/kg diet	0.1	0.013	1.17			9			Hill et al., 1976
Coturnix japonica	8 d	MORT	5		mg/kg diet	0.01	0.0033	1.4			5			Kreitzer and Heinz, 1974
Coturnix japonica	24 w	BDWT	25		mg/kg diet	0.135	0.018	3.33			25			Reading et al., 1976
Coturnix japonica	16 w	RSUC	5	10	mg/kg diet	0.135	0.023	0.852	1.7		5	10		Reading et al., 1976
Coturnix japonica	24 w	RSUC		10	mg/kg diet	0.132	0.02		1.52			10		Reading et al., 1976
Coturnix japonica	16 w	MORT	5	10	mg/kg diet	0.135	0.023	0.852	1.7		5	10		Reading et al., 1976
Coturnix japonica	24 w	MORT		10	mg/kg diet	0.12	0.02		1.67			10		Reading et al., 1976
Coturnix japonica	10 w	BDWT	1		mg/kg diet	0.1335	0.0157	0.118			≥ 1		✓,3	Shellenberger, 1978
Coturnix japonica	10 w	TPRD	1		mg/kg diet	0.1335	0.0157	0.118			≥ 1		✓,3	Shellenberger, 1978
Coturnix japonica	18 w	RSUC	10	20	mg/kg diet	0.1	0.013	1.3	2.6		10	20		Walker et al., 1969
Coturnix japonica	18 w	MORT	10	20	mg/kg diet	0.1	0.013	1.3	2.6		10	20		Walker et al., 1969
Gallus domesticus	28 d	BDWT	10		mg/kg diet	1.042	0.0598	0.574			10			Muller and Lockman, 1973
Gallus domesticus	20 w	BDWT	50		mg/kg diet	2.41	0.0524	1.09			50			Ahmed et al., 1978
Gallus domesticus	12 w	BDWT	20		mg/kg diet	1.541	0.09	1.17			20			Davison and Sell, 1972
Gallus domesticus	28 d	BDWT	10		mg/kg	1.042	0.0598	10			167			Muller and Lockman, 1973

Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [52]			(no) effect level as dietary concentration		Notes[b]	Ref
								NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
Gallus domesticus	5 mo	BDWT		10	mg/kg diet	2.236	0.0983	0.439				10	✓,4	Brown et al., 1974
Gallus domesticus	13 mo	ESTH	20		mg/kg diet	2.229	0.0981	0.88			20		✓,4	Brown et al., 1974
Gallus domesticus	20 w	SPCL	50		mg/kg diet	2.41	0.0524	1.09			50			Ahmed et al., 1978
Gallus domesticus	12 w	TPRD	20		mg/kg diet	1.541	0.09	1.17			20			Davison and Sell, 1972
Gallus domesticus	13 mo	MORT	20		mg/kg diet	2.229	0.0981	0.88			20		✓,4	Brown et al., 1974
Gallus domesticus	12 w	MORT	20		mg/kg diet	1.541	0.09	1.17			20			Davison and Sell, 1972
Gallus domesticus	90 d	MORT	10	15	mg/kg bw	1.694	0.082	10	15			310		Eden, 1951
Gallus domesticus	12 w	MORT		25	mg/kg diet	2.62	0.0682		0.651			25		Ahmed et al., 1978
Numida meleagris	21 mo	PROG	1.5	5	mg/kg diet	1.28	0.0674	0.0671	0.223		1.5	5		Wiese et al., 1968
Numida meleagris	21 mo	MORT	1.5	5	mg/kg diet	1.28	0.0539	0.0537	0.179		1.5	5		Wiese et al., 1968
Phasianus colchicus	13 w	BDWT	0.286	0.571	mg/d	1.101	0.062	0.26	0.519		4.6	9.2	X	Atkins and Linder, 1967
Phasianus colchicus	90 d	BDWT	70	100	mg/kg diet	0.95	0.0563	4.15	5.93		70	100		Genelly and Rudd, 1955
Phasianus colchicus	13 w	BDWT		0.286	mg/d	1.212	0.066	0.236			4.3		X	Atkins and Linder, 1967
Phasianus colchicus	74 d	BDWT		25	mg/kg diet	0.95	0.0366	0.96				25		Genelly and Rudd, 1955
Phasianus colchicus	13 w	EGWT	0.286	0.571	mg/d	1.101	0.062	0.26	0.519		4.6	9.2	X	Atkins and Linder, 1967
Phasianus colchicus	13 w	TPRD	0.571	0.857	mg/d	1.27	0.068	0.45	0.675		8.4	12.6	X	Atkins and Linder, 1967
Phasianus colchicus	22 d	CYNG	0.9		mg/kg bw/d	0.95	0.0563	0.9						Cool et al., 1972
Phasianus colchicus	17 w	FTEG	0.86	1.43	mg/org/d	0.95	0.0563	0.905	1.5		15.3	25.4		Dahlgren and Linder, 1974
Phasianus colchicus	42 d	HTCH	1		mg/d	0.953	0.0564	1.05						Stromborg, 1977
Phasianus colchicus	16 w	ESTH	10		mg/d	0.95	0.0563	10.5						Dahlgren and Linder, 1974
Phasianus colchicus	6 mo	PROG		1.12	mg/org/d	0.95	0.0563		1.18			19.89		Genelly and Rudd, 1956
Phasianus colchicus	60 d	MORT	25	50	mg/kg diet	0.95	0.0446	1.17	2.35		25	50		Genelly and Rudd, 1955
Phasianus colchicus	90 d	MORT	25	70	mg/kg diet	0.95	0.0563	1.48	4.15		25	70		Genelly and Rudd, 1955
Phasianus colchicus	17 w	MORT		0.57	mg/org/d	1.3	0.069		0.44			8.26		Dahlgren and Linder, 1974
Tyto alba	2 y	EGWT		0.58	mg/kg diet	0.524	0.0382		0.0445		≥ 0.58		✓,3,5	Mendenhall et al., 1983
Tyto alba	2 y	MORT	0.58		mg/kg diet	0.524	0.0382	0.0445			≥ 0.58		✓,2	Mendenhall et al., 1983

Notes

a: ABNM = abnormality, in this case most likely associated with ovary; BDWT = bodyweight; DEYO = death young; GREP = general reproduction; GSTT = gestation time; ODVP = organ development time; ORWT = organ weight changes, in this case ovary weight; OTHR = other, exact endpoint cannot be deduced from reference; OVRT = ovulation rate; PROG = progeny counts; PRWT = progeny weight; PVOP = not explained in the Eco-SSL report and cannot be decuced from the (abstract) of the reference; RBEH = reproductive behaviour; RHIS = reproductive histology; RSUC = reproductive success; TEWT = testes weight

b: ✓ = full reference or abstract checked; X = reference or abstract not available

1: <5% effect at lowest dose tested, NOAEC set at 1.6 mg/kg fd

2: NOEC given as 10 mg/kg fd in Romijn et al., but authors consider 2.5 mg/kg fd as no effect dose

3: no effects observed at single dose tested or at highest dose tested, NOAEL/NOAEC presented as ≥-value

4: study also used in Romijn et al.; NOEC set to 10 mg/kg fd (<10% effect on body weight)

5: single concentration tested; 0.58 mg/kg diet reported as LOAEL in [52], but original reference states that no significant effect on egg characteristics were observed

Appendix 5. Toxicity of drins to mammals

Table A5.1 Toxicity of aldrin to mammals as reported by Van de Plassche et al. [22].

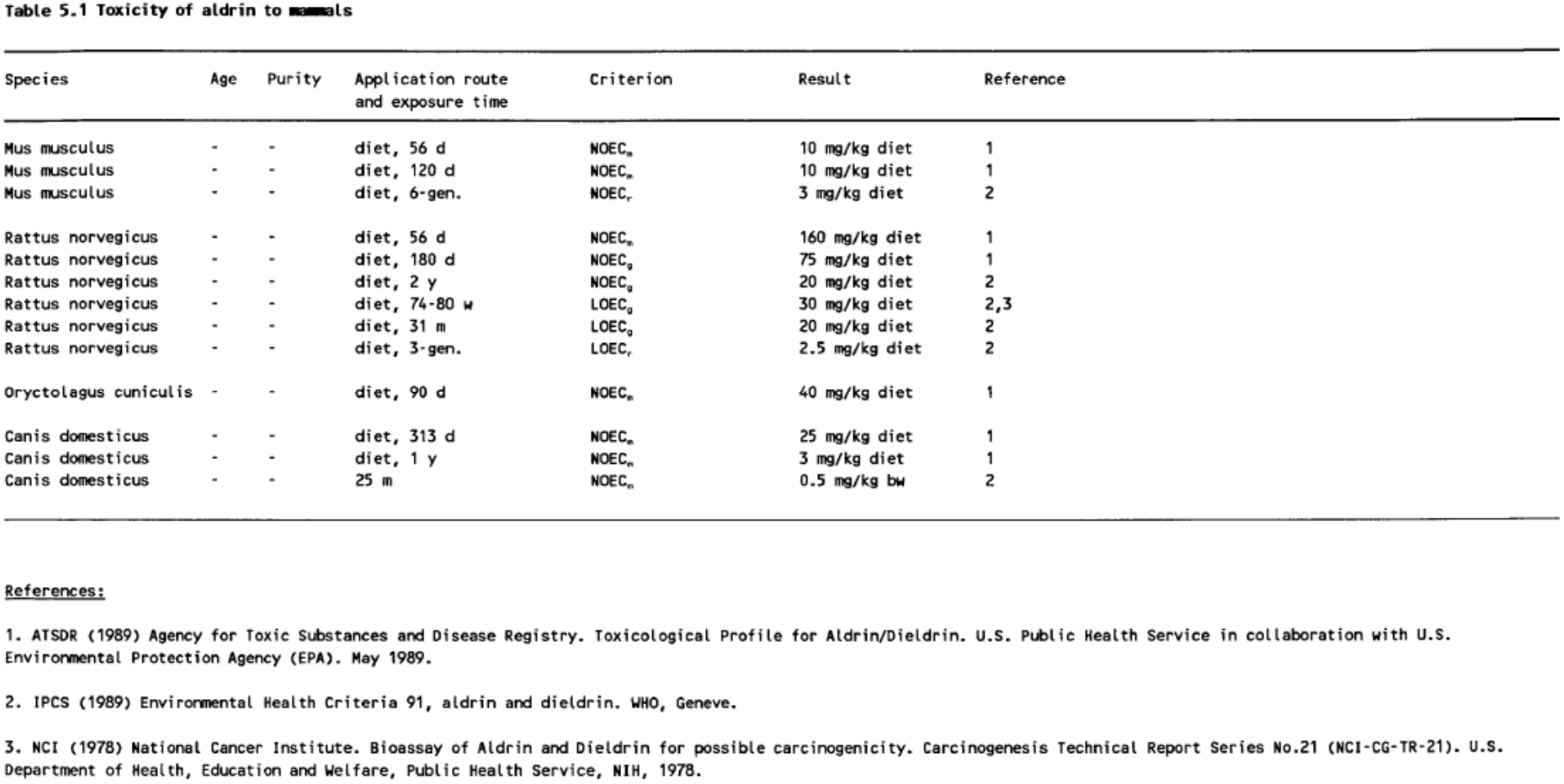


Table 5.1 Toxicity of aldrin to mammals

Species	Age	Purity	Application route and exposure time	Criterion	Result	Reference
Mus musculus	-	-	diet, 56 d	$NOEC_m$	10 mg/kg diet	1
Mus musculus	-	-	diet, 120 d	$NOEC_m$	10 mg/kg diet	1
Mus musculus	-	-	diet, 6-gen.	$NOEC_r$	3 mg/kg diet	2
Rattus norvegicus	-	-	diet, 56 d	$NOEC_m$	160 mg/kg diet	1
Rattus norvegicus	-	-	diet, 180 d	$NOEC_g$	75 mg/kg diet	1
Rattus norvegicus	-	-	diet, 2 y	$NOEC_g$	20 mg/kg diet	2
Rattus norvegicus	-	-	diet, 74-80 w	$LOEC_g$	30 mg/kg diet	2,3
Rattus norvegicus	-	-	diet, 31 m	$LOEC_g$	20 mg/kg diet	2
Rattus norvegicus	-	-	diet, 3-gen.	$LOEC_r$	2.5 mg/kg diet	2
Oryctolagus cuniculis	-	-	diet, 90 d	$NOEC_m$	40 mg/kg diet	1
Canis domesticus	-	-	diet, 313 d	$NOEC_m$	25 mg/kg diet	1
Canis domesticus	-	-	diet, 1 y	$NOEC_n$	3 mg/kg diet	1
Canis domesticus	-	-	25 m	$NOEC_n$	0.5 mg/kg bw	2

References:

1. ATSDR (1989) Agency for Toxic Substances and Disease Registry. Toxicological Profile for Aldrin/Dieldrin. U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency (EPA). May 1989.

2. IPCS (1989) Environmental Health Criteria 91, aldrin and dieldrin. WHO, Geneve.

3. NCI (1978) National Cancer Institute. Bioassay of Aldrin and Dieldrin for possible carcinogenicity. Carcinogenesis Technical Report Series No.21 (NCI-CG-TR-21). U.S. Department of Health, Education and Welfare, Public Health Service, NIH, 1978.

Table A5.2 Toxicity of endrin to mammals as reported by Van de Plassche et al. [22].

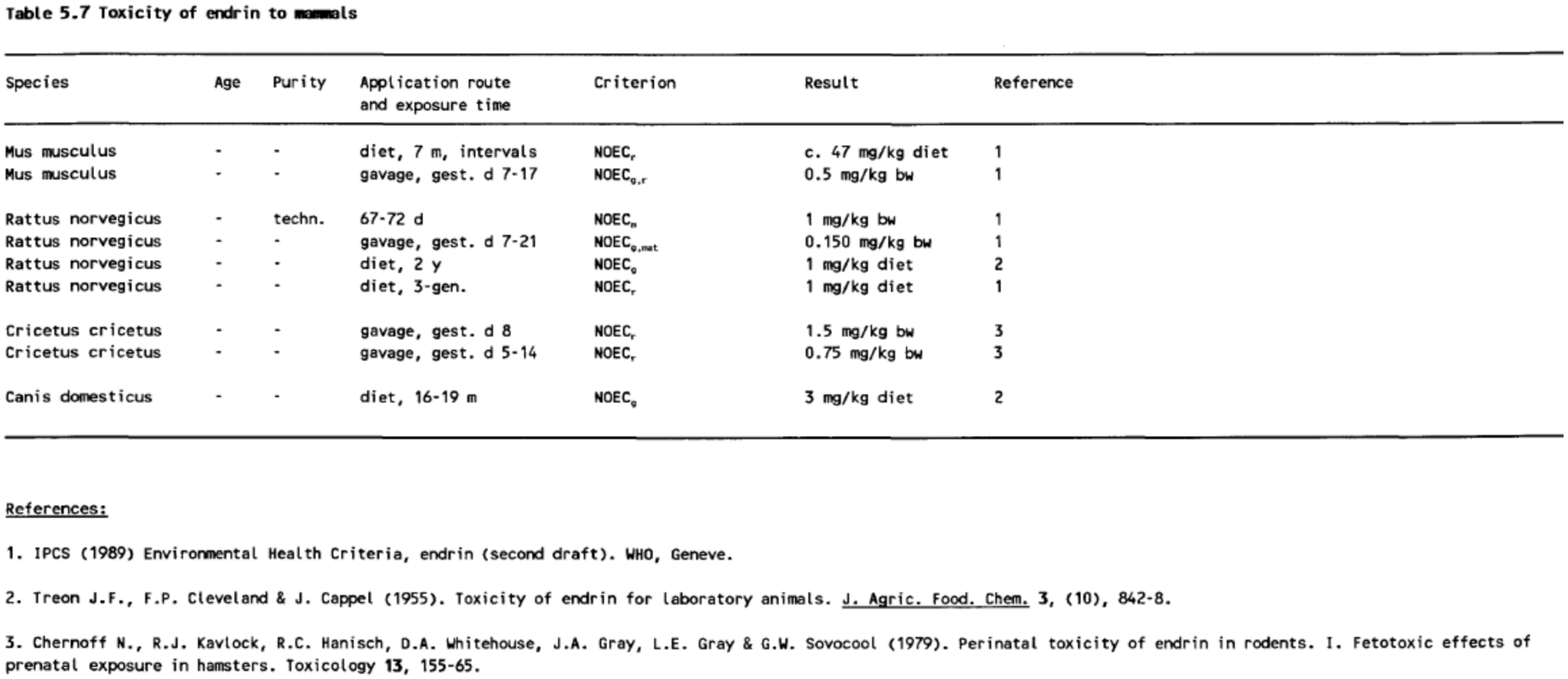


Table 5.7 Toxicity of endrin to mammals

Species	Age	Purity	Application route and exposure time	Criterion	Result	Reference
Mus musculus	-	-	diet, 7 m, intervals	$NOEC_r$	c. 47 mg/kg diet	1
Mus musculus	-	-	gavage, gest. d 7-17	$NOEC_{g,r}$	0.5 mg/kg bw	1
Rattus norvegicus	-	techn.	67-72 d	$NOEC_m$	1 mg/kg bw	1
Rattus norvegicus	-	-	gavage, gest. d 7-21	$NOEC_{g,mat}$	0.150 mg/kg bw	1
Rattus norvegicus	-	-	diet, 2 y	$NOEC_g$	1 mg/kg diet	2
Rattus norvegicus	-	-	diet, 3-gen.	$NOEC_r$	1 mg/kg diet	1
Cricetus cricetus	-	-	gavage, gest. d 8	$NOEC_r$	1.5 mg/kg bw	3
Cricetus cricetus	-	-	gavage, gest. d 5-14	$NOEC_r$	0.75 mg/kg bw	3
Canis domesticus	-	-	diet, 16-19 m	$NOEC_g$	3 mg/kg diet	2

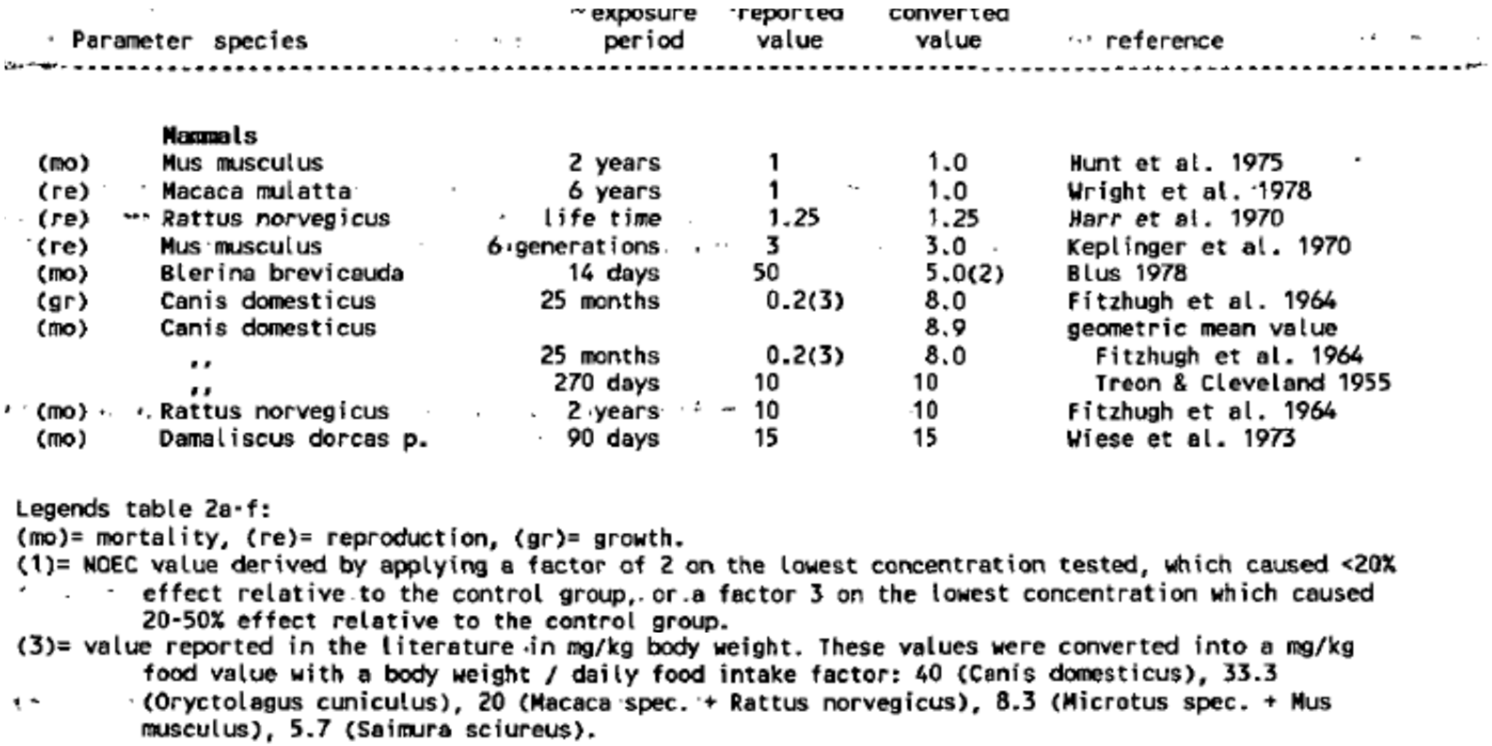
References:

1. IPCS (1989) Environmental Health Criteria, endrin (second draft). WHO, Geneve.

2. Treon J.F., F.P. Cleveland & J. Cappel (1955). Toxicity of endrin for laboratory animals. J. Agric. Food. Chem. **3**, (10), 842-8.

3. Chernoff N., R.J. Kavlock, R.C. Hanisch, D.A. Whitehouse, J.A. Gray, L.E. Gray & G.W. Sovocool (1979). Perinatal toxicity of endrin in rodents. I. Fetotoxic effects of prenatal exposure in hamsters. Toxicology **13**, 155-65.

Table A5.3 Toxicity of dieldrin to mammals as reported by Van de Plassche et al. [20]. Values are presented in mg/kg$_{fd}$.



Parameter	species	exposure period	reported value	converted value	reference
	Mammals				
(mo)	Mus musculus	2 years	1	1.0	Hunt et al. 1975
(re)	Macaca mulatta	6 years	1	1.0	Wright et al. 1978
(re)	Rattus norvegicus	life time	1.25	1.25	Harr et al. 1970
(re)	Mus musculus	6 generations	3	3.0	Keplinger et al. 1970
(mo)	Blerina brevicauda	14 days	50	5.0(2)	Blus 1978
(gr)	Canis domesticus	25 months	0.2(3)	8.0	Fitzhugh et al. 1964
(mo)	Canis domesticus			8.9	geometric mean value
	"	25 months	0.2(3)	8.0	Fitzhugh et al. 1964
	"	270 days	10	10	Treon & Cleveland 1955
(mo)	Rattus norvegicus	2 years	10	10	Fitzhugh et al. 1964
(mo)	Damaliscus dorcas p.	90 days	15	15	Wiese et al. 1973

Legends table 2a-f:
(mo)= mortality, (re)= reproduction, (gr)= growth.
(1)= NOEC value derived by applying a factor of 2 on the lowest concentration tested, which caused <20% effect relative to the control group, or a factor 3 on the lowest concentration which caused 20-50% effect relative to the control group.
(3)= value reported in the literature in mg/kg body weight. These values were converted into a mg/kg food value with a body weight / daily food intake factor: 40 (Canis domesticus), 33.3 (Oryctolagus cuniculus), 20 (Macaca spec. + Rattus norvegicus), 8.3 (Microtus spec. + Mus musculus), 5.7 (Saimura sciureus).

Table A5.4 Effects of dieldrin on mortality, growth and reproduction of mammals as reported in the Eco-SSL report of the US EPA [24,52]. No or Lowest Adverse Effect Levels (NOAEL/LOAEL) expressed as dietary dose [mg/kg$_{bw}$ d] are calculated in the Eco-SSL report if study results is reported as dietary concentration [mg/kg$_{diet}$], based on reported or default data on body weight and food ingestion. Shaded columns: when original study results were expressed as daily dose, No or Lowest Observed Adverse Effect Concentrations (NOAEC/LOAEC) expressed as dietary concentration [mg/kg$_{fd}$] were recalculated for the present report using data on body weight and food ingestion. See notes for comments on study results.

Species	Exposure Duration	Endpoint[a]	Study NOAEL	Study LOAEL	Units	Body weight [kg]	Food ingestion [kg/d]	(no) effect level as dietary dose in [24]			(no) effect level as dietary concentration		Notes[b]	Ref
								NOAEL [mg/kg$_{bw}$.d]	LOAEL [mg/kg$_{bw}$.d]		NOAEC [mg/kg$_{fd}$]	LOAEC [mg/kg$_{fd}$]		
Canis familiaris	104 w	BDWT	0.05		mg/kg bw/d	14	0.6013	0.05			1.2			Walker et al., 1969
Canis familiaris	47 d	BDWT	0.6	2	mg/kg bw/d	11.34	0.5056	0.6	2		13	45		Kitselman and Borgmann, 1952
Canis familiaris	104 w	TEWT	0.05		mg/kg bw/d	14	0.6013	0.05			1.2			Walker et al., 1969
Mus musculus	90 d	BDWT	10		mg/kg diet	0.0325	0.0041	1.26						Kolaja et al., 1996
Mus musculus	10 d	BDWT	3	6	mg/kg bw/d	0.0288	0.0037	2.61	5.22		23	47		Chernoff et al., 1975
Mus musculus	9 d	BDWT	4		mg/kg bw/d	0.0285	0.0037	4			31			Dix et al., 1977
Mus musculus	9 d	PLBR	4		mg/kg bw/d	0.0285	0.0037	4			31			Dix et al., 1977
Mus musculus	5 d	TEWT	5		mg/kg bw/d	0.04	0.0049	5			41			Schein and Thomas, 1975
Mus musculus	13 w	RSUC		2.5	mg/kg diet	0.0288	0.0037		0.278			2.5		Virgo and Bellward, 1975
Mus musculus	120 d	PROG		5	mg/kg diet	0.0247	0.0033		0.564			5		Good and Ware, 1969
Mus musculus	60 d	RSUC		5	mg/kg diet	0.0288	0.0037		0.646			5		Virgo and Bellward, 1975
Odocoileus virginianus	3 y	BDWT		0.14	mg/kg bw/d	32.2	0.9979		0.14		< 4.5	4.5	X,1	Murphy and Korschgen, 1970
Odocoileus virginianus	3 y	PRWT	0.14	0.72	mg/kg bw/d	36.78	1.043	0.14	0.72		4.9	25		Murphy and Korschgen, 1970
Oryctolagus cuniculus	5 w	BDWT		50	mg/L	2.4	0.2177		4.31					Wasserman et al., 1972
Ovis aries	32 w	BDWT	1	2	mg/kg bw/d	40	1.4251	0.87	1.74		28	56	✓,2	Davison, 1970
Rattus norvegicus	20 w	BDWT	5	25	mg/kg diet	0.447	0.0354	0.392	1.96		5	25		Treon et al., 1959
Rattus norvegicus	2 y	BDWT	9.66		mg/kg diet	0.397	0.0321	0.81			9.66			Walker et al., 1969
Rattus norvegicus	90 d	BDWT	10		mg/kg diet	0.325	0.0273	0.839			10			Kolaja et al., 1996
Rattus norvegicus	28 w	BDWT	12.5	25	mg/kg diet	0.3537	0.0292	1.02	2.05		12.5	25		Treon et al., 1959
Rattus norvegicus	24 w	BDWT	1.43		mg/kg bw/d	0.2	0.0103	1.43			28			Krishnamurthy et al., 1965
Rattus norvegicus	10 d	BDWT	3	6	mg/kg bw/d	0.3846	0.0313	2.61	5.22		37	74		Chernoff et al., 1975
Rattus norvegicus	8 w	BDWT	8		mg/kg bw/d	0.152	0.0111	8			110			Jones et al., 1974
Rattus norvegicus	4 d	BDWT	100	200	mg/kg diet	0.216	0.0195	9.02	18		100	200		Foster, 1968
Rattus norvegicus	2 y	BDWT	150		mg/kg diet	0.475	0.0373	11.8			150			Fitzhugh et al., 1964
Rattus norvegicus	6 mo	BDWT		2	mg/kg bw/d	0.35	0.04		0.4			17.5		Shakoori et al., 1984
Rattus norvegicus	50 d	BDWT		10	mg/kg diet	0.48	0.0336		0.7			10		Mehrotra et al., 1988
Rattus norvegicus	8 w	BDWT		2.64	mg/kg bw/d	0.512	0.0396		2.64			34		Kimbrough et al., 1971
Rattus norvegicus	15 d	BDWT		5	mg/kg bw/d	67	2.1777		5			154		Bandyopadhyay et al., 1982
Rattus norvegicus	4 d	BDWT		200	mg/kg diet	0.1662	0.0137		16.5			200		Foster, 1968
Rattus norvegicus	750 d	PROG	0.16	0.31	mg/kg diet	0.156	0.0149	0.015	0.03		0.16	0.31	X,3	Harr et al., 1970
Rattus norvegicus	2 y	TEWT	9.66		mg/kg diet	0.397	0.0321	0.81			9.66			Walker et al., 1969
Rattus norvegicus	10 d	PRFM	6		mg/kg bw/d	0.3846	0.0313	5.22			73.7			Chernoff et al., 1975
Rattus norvegicus	127 d	FERT		2.5	mg/kg diet	0.2024	0.0185		0.228			2.5		Treon et al., 1959

a: BDWT = bodyweight; FET = fertility; PLBR = pairs with litter or brood; PROG = progeny counts; PRFM = sexual performance; RSUC = reproductive success; TEWT = testes weight
b: ✓ = full reference or abstract checked; X = reference or abstract not available
1: effect level unknown (reference/abstract not available), NOAEC cannot be extrapolated from LOAEL and is presented as a <-value
2: mistakenly converted to daily dose in [52], result is already expressed as daily dose
3: NOAEC of this study is presented as 1.25 mg/kg fd in [20,53], see Table A5.3. Latter is used.

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