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

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RIVM report 607711009/2012

R. van Herwijnen

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Colophon

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This investigation has been performed by order and for the account of Ministry of Infrastructure and the Environment (I&M), Directorate General of the Environment (DGM), Directorate of Sustainable production (DP), within the framework of project 607711, soil quality, prevention and risk assessment.

Abstract

Environmental risk limits for organotin compounds

RIVM has derived environmental risk limits (ERLs) for three organotin compounds: dibutyltin, tributyltin and triphenyltin. These are the most widely used organotin compounds. Dibutyltin has several uses, for example in the plastic PVC and in printer toner. Tributyltin and triphenyltin are mainly used for wood conservation and as antifouling. Triphenyltin was also used as plant protection product for potatoes. The use as antifouling has been banned within Europe since 2003, and there is no authorisation anymore for the use of triphenyltin as plant protection product.

Intervention values for soil
The environmental risk limits have been derived because they are needed to determine intervention values for soil and groundwater. In case an intervention value is exceeded, the (polluted) soil will be considered for remediation. For this purpose, ERLs for groundwater and soil are required. ERLs for soil were not available and have been derived for this report. ERLs for water were already derived within other frameworks and have been adopted. ERLs for surface water and sediment are also reported in this report because they are related to soil and groundwater. In this way a complete overview of the available ERLs for each compound is given.

The derived environmental risk limits for soil and groundwater
One of the derived ERLs is the Serious Risk Concentration (SRC). At this concentration, harmful effects for soil organisms are expected. The determined SRCs for soil are 28; 0.052 and 0.24 milligram per kilogram dry weight soil for dibutyltin, tributyltin and triphenyltin respectively. For groundwater, the SRCs are respectively 50; 0.046 and 0.40 microgram per liter.

Direct and indirect effects
The SRC is based on the annual average concentrations in soil, water and sediment. For this report, two routes of exposure have been examined: direct exposure of water or soil organisms, and indirect exposure of birds or mammals consuming water or soil organisms (food chain). Indirect exposure of humans where it concerns intervention values is evaluated in a separate report (Brand et al., 2012).

Keywords:
dibutyltin, triphenyltin, tributyltin, groundwater, water, soil, environmental risk limits

Rapport in het kort

Milieurisicogrenzen voor organotinverbindingen

Het RIVM heeft in opdracht van het ministerie van Infrastructuur en Milieu (I&M), milieurisicogrenzen voor drie organotinverbindingen in (grond)water, sediment en bodem vastgesteld. De drie meest voorkomende verbindingen in het milieu zijn: dibutyltin, tributyltin en trifenyltin. Dibutyltin wordt in verscheidene toepassingen gebruikt, bijvoorbeeld in de kunststof pvc en in printertoners. Tributyltin en trifenyltin zijn voornamelijk gebruikt als middel om hout te conserveren en om te voorkomen dat er onder water op de romp van schepen organismen groeien (aangroeiwerend middel). Trifenyltin werd ook gebruikt als gewasbeschermingsmiddel in de aardappelteelt. Het gebruik als aangroeiwerend middel is in Europa sinds 2003 niet meer toegestaan en trifenyltin heeft ook geen authorisatie meer als gewasbescheringsmiddel.

Interventiewaarden bodem
De milieurisicogrenzen zijn afgeleid omdat ze nodig zijn om de zogeheten interventiewaarden te bepalen. Als een interventiewaarde wordt overschreden, komt de (vervuilde) bodem in aanmerking voor sanering. Voor dit doel zijn alleen milieurisicogrenzen voor grondwater en bodem nodig. De milieurisicogrenzen voor de individuele organotins in bodem waren nog niet beschikbaar en zijn voor dit onderzoek afgeleid. Milieurisicogrenzen voor water waren al eerder afgeleid binnen andere kaders en zijn overgenomen. De milieurisicogrenzen voor oppervlaktewater en sediment zijn ook in het rapport vermeld, omdat deze aan bodem en grondwater zijn gerelateerd. Dit geeft een volledig overzicht.

De milieurisicogrenzen voor bodem en grondwater
Een van de afgeleide milieurisicogrenzen is het Ernstig Risiconiveau (ER). Dit is de concentratie waarbij schadelijke effecten van de stof voor de bodem te verwachten zijn. De bepaalde ER's voor bodem zijn 28; 0.052 en 0.24 milligram per kilogram drooggewicht bodem, voor achtereenvolgens dibutyltin, tributyltin en trifenyltin. Voor grondwater zijn de ER's respectievelijk 50; 0,046 en 0,40 microgram per liter.

Directe en indirecte effecten
Het ER is gebaseerd op de jaargemiddelde concentraties in bodem, water en sediment. Hiervoor zijn in dit rapport twee routes onderzocht: de directe effecten op waterorganismen en de indirecte effecten op vogels en zoogdieren via het nuttigen van de waterorganismen (voedselketen). Effecten voor mensen bij interventiewaarden worden in een separaat rapport geëvalueerd.

Trefwoorden:
dibutyltin, trifenyltin, tributyltin, grondwater, water, bodem, milieurisicogrenzen

Contents

Summary

In this report, the RIVM presents Environmental Risk Limits (ERLs) for organotin compounds in surface water, groundwater, sediment and soil. The organotin compounds involved are dibutyltin, tributyltin and triphenyltin. Dibutyltin compounds are used in various applications like stabiliser in PVC and charge regulator in printer toner; tributyltin and triphenyltin are/were mainly used in biocidal applications like antifouling and wood preservation. The use of tributyltin and triphenyltin as antifouling is not allowed anymore since 2003. Based on the data from ERL derivation for other frameworks and additional information obtained from the open literature, ecotoxicological environmental risk limits for the three organotins in groundwater and soil have been derived that can be used to set intervention values for contaminated soils. ERLs for fresh and salt surface water and sediment are also presented when available to give a complete overview of the available ERLs. The methods used are in accordance with the methodology of the WFD (Water Framework Directive) and INS (International and National environmental quality standards for Substances in the Netherlands).

For the setting of intervention values, two types of ERL are considered, each representing a different protection aim:

- The Maximum Permissible Concentration for ecosystems (MPC_{eco}) - the concentration in an environmental compartment at which no effect to be rated as negative is to be expected for ecosystems. Separate MPC_{eco} values are derived for the freshwater and saltwater environment;
- Serious Risk Concentration for ecosystems (SRC_{eco}) - the concentration in (ground)water, sediment or soil at which possibly serious ecotoxicological effects are to be expected.

The MPC_{water} is equivalent to the long-term water quality standards that is indicated as AA-EQS in the WFD-guidance. Where applicable, ERLs are derived for freshwater and saltwater. An overview of the ERLs is presented in Table 1. It should be mentioned that these ERLs are only based on direct exposure of water or soil organisms and indirect exposure of birds or mammals consuming water or soil organisms (food chain). Indirect exposure of humans has not been assessed.

Table 1. Environmental risk limits for the ecosystem for organotin compounds in surface water, groundwater, sediment and soil

Compartiment	dibutyltin	tributyltin	triphenyltin
Surface water			
MPC_{fw} (µg/L)	0.15	0.2 x 10^{-3}	0.23 x 10^{-3}
MPC_{sw} (µg/L)	0.15	0.2 x 10^{-3}	0.23 x 10^{-3}
$MAC_{fw, eco}$ (µg/L)	0.30	1.5 x 10^{-3}	0.47
$MAC_{sw, eco}$ (µg/L)	0.15	0.2 x 10^{-3}	0.47
SRC_{water} (µg/L)	16	26 x 10^{-3}	0.10
Groundwater			
$MPC_{gw, eco}$ (µg/L)	0.15	0.2 x 10^{-3}	0.23 x 10^{-3}
$SRC_{gw, eco}$ (µg/L)	50	46 x 10^{-3}	0.40
Sediment [a]			
$MPC_{sediment, eco}$ (µg/kg_{dwt})	0.37 x 10^{3}	0.01 [c]	2.2 x 10^{-3}
$SRC_{sediment, eco}$ (µg/kg_{dwt})	123 x 10^{3}	27	2.2
Soil [b]			
MPC_{soil} (mg/kg_{dwt})	0.37	2.3 x 10^{-6}	4.0 x 10^{-3}
SRC_{soil} (mg/kg_{dwt})	28	52 x 10^{-3}	0.24
geometric mean of MPC_{soil} and SRC_{soil} (mg/kg_{dwt})	3.2	0.35 x 10^{-3}	0.031

n.d. = not derived

[a] Sediment values are expressed for Dutch standard sediment with 10% organic matter.

[b] Soil values are expressed for Dutch standard soil with 10% organic matter.

[c] This value should be considered as a worst case estimate.

1 Introduction

1.1 Project framework

In this report, Environmental Risk Limits (ERLs) for surface water (freshwater and marine), groundwater, sediment and soil ecosystems are derived for three organotin compounds: dibutyltin, tributyltin and triphenyltin. More details on the compounds are given in the individual chapters. The aim of this report is to present ERLs that are relevant for the setting of intervention values for soil contamination. The intervention values are evaluated in a separate report (Brand et al., 2012). ERLs for fresh and salt surface water and sediment are also presented when available to give a complete overview of the available ERLs. In this report, only ERLs relevant for the ecosystem are considered; the risk for humans is not considered because this risk is approached differently for the setting of intervention values for soil. The following ERLs are considered:

- Maximum Permissible Concentration for ecosystems (MPC_{eco}) - the concentration in an environmental compartment at which no effect to be rated as negative is to be expected for ecosystems. Separate MPC_{eco} values are derived for the freshwater and saltwater environment;
- Serious Risk Concentration for ecosystems (SRC_{eco}) - the concentration in (ground)water, sediment or soil at which possibly serious ecotoxicological effects are to be expected. The SRC_{eco} is valid for the freshwater and saltwater compartment.

1.2 Current MPCs

Risk limits at the time of publication of this report are given in Table 2. Actual risk limits can be found at the website 'Risico's van stoffen' (http://www.rivm.nl/rvs/). For the aquatic environment, no new ERLs are derived, but ERLs derived in other frameworks are adopted. For soil, new ERLs are derived since no ERLs are available.

Table 2. Risk limits for the three organotin compounds at the time of publication of this report

	Fresh surface water		Salt surface water		Groundwater
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
	MPC	MAC*	MPC	MAC *	MPC
DBT	0.09				
TBT	0.0002	0.0015	0.0002	0.0015	1.0×10^{-4}
TPT	0.005		0.0009		5×10^{-5}

* MAC = Maximum Acceptable Concentration for short term exposure

1.3 Methodology

The methodology for risk limit derivation is described in detail in the INS-guidance document (Van Vlaardingen and Verbruggen, 2007), which is further referred to as the INS-Guidance. The methodology is based on the Technical Guidance Document (TGD), issued by the European Commission and developed in support of the risk assessment of new notified chemical substances, existing substances and biocides (EC, 2003), and on the Manual for the derivation of Environmental Quality Standards in accordance with the Water Framework Directive (Lepper, 2005). The European guidance under the framework of WFD is currently being revised; the final draft has been approved recently (March, 2011) by the Strategic Coordination Group under the European Water Directors. The terminology is harmonised as much as possible and the new guidance is followed in the case it deviates from the INS-guidance.

1.3.1 Data collection

For the water compartment, ERLs for all three compounds have recently been derived within other frameworks (EC, 2005, ICBR, 2009, Van Herwijnen et al., 2012). These ERLs have been adopted where available. In those cases that an aquatic ERL was not derived in these reports, the collected dataset was used for additional derivation. For soil toxicity data and soil/sediment sorption data, an on-line literature search has been performed using Scopus (www.scopus.com). The search for soil toxicity data was performed on 8 April 2011. Additionally, a search for soil/sediment sorption data of dibutyltin and tributyltin was performed on 19 August 2011. The latter search was performed because sorption data were necessary for the application of equilibrium partitioning.

1.3.2 Data evaluation

Soil ecotoxicity studies were screened for relevant endpoints (i.e. those endpoints that have consequences at the population level of the test species) and thoroughly evaluated with respect to the validity (scientific reliability) of the study. A detailed description of the evaluation procedure is given in section 2.2.2 and 2.3.2 of the INS-Guidance and in the Annex to the draft EQS-guidance under the WFD. In short, the following reliability indices (Ri) were assigned, based on Klimisch et al. (1997):

Ri 1: Reliable without restriction
’Studies or data […] generated according to generally valid and/or internationally accepted testing guidelines (preferably performed according to GLP), or in which the test parameters documented are based on a specific (national) testing guideline […], or in which all parameters described are closely related/comparable to a guideline method’

Ri 2: Reliable with restrictions
’Studies or data […] (mostly not performed according to GLP), in which the test parameters documented do not totally comply with the specific testing guideline, but are sufficient to accept the data or in which investigations are described which cannot be subsumed under a testing guideline, but which are nevertheless well documented and scientifically acceptable’

Ri 3: Not reliable
’Studies or data […] in which there are interferences between the measuring system and the test substance, or in which organisms/test systems were used which are not relevant in relation to the exposure (e.g. unphysiologic pathways of application), or which were carried out or generated according to a method which is not acceptable, the documentation of which is not sufficient for an assessment and which is not convincing for an expert judgment’

Ri 4: Not assignable
'Studies or data […] which do not give sufficient experimental details and which are only listed in short abstracts or secondary literature (books, reviews, etc.)'

Citations
In case of (self-)citations, the original (or first cited) value is considered for further assessment, and an asterisk is added to the Ri of the endpoint that is cited.

All available studies are summarised in data-tables that are included as annexes to this report. These tables contain information on species characteristics, test conditions and endpoints. Explanatory notes are included with respect to the assignment of the reliability indices.

In the aggregated data tables only one effect value per species is presented. When for a species several effect data are available, the geometric mean of multiple values for the same endpoint is calculated where possible. Subsequently, when several endpoints are available for one species, the lowest of these endpoints (per species) is reported in the aggregated data table.

1.3.3 Physico-chemical data

The aquatic ERLs for dibutyltin and tributyltin are adopted from other reports and some additional data have also been adopted. The physico-chemical data in these reports are however limited. Therefore, for the physico-chemical data of these substances, the original sources have been checked where possible and supplemented with sources as indicated in the INS-guidance.

1.3.4 Species of organotin compounds

All three organotin compounds are available in different species that could have a different toxicity. Therefore, endpoints for toxicity are not pooled for the different species and the endpoint for the most toxic species is selected where available.

1.3.5 Correction for the use of laboratory feed in bird and mammal test

In the assessment factors that are applied to use toxicity data for birds and mammals for the assessment of secondary poisoning, a factor of three is involved. This correction factor is applied to correct for the difference in calorific value of the feed used in the laboratory trials in comparison to the feed consumed by wild animals in the field. This value is based on the consumption of fish for the assessment in aquatic ecosystems. This value is however also used for the assessment in soil ecosystems and is currently under discussion for this approach since the calorific value of earthworms is lower than that for fish. Based on this, the exposure through secondary poisoning in soil ecosystems might be underestimated using the factor of three. The factor of three is used for as long as no alternative value is decided upon but the assessments for secondary poisoning in soil ecosystems should be re-evaluated when a new value becomes available.

1.4 Status of the results

The results presented in this report have been discussed by the members of the scientific advisory group for the INS-project (WK-INS). It should be noted that the ERLs in this report are scientifically derived values, based on (eco)toxicological, fate and physico-chemical data. They serve as advisory values for the Dutch Steering Committee for Substances, which is appointed to set the Environmental Quality Standards (EQSs). ERLs should thus be considered as advisory values that do not have an official status.

2 Dibutyltin

2.1 Data sources

For dibutyltindichloride, aquatic ERLs have been derived by the 'Internationale Commissie ter Bescherming van de Rijn – ICBR' (International Commission for the Protection of the Rhine) according to the requirements of the Water Framework Directive. These ERLs are adopted in Dutch legislation and therefore these ERLs are also adopted in this report. The derivation of these ERLs has been reported in the report 'Afleiding van milieukwaliteitsnormen voor Rijnrelevante stoffen' (ICBR, 2009). In ICBR (2009), the ecotoxicological ERLs are expressed for dibutyltindichloride. In this report, the ERLs are expressed as the DBT-cation.

2.2 Substance information

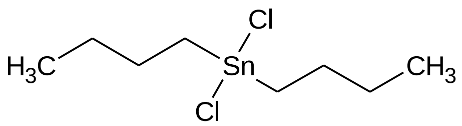
2.2.1 Information on production and use

Dibutyltin compounds are being used as stabilisers in PVC, as catalysers for polymers and as coating for glass. Other uses are as regulator for the charge in printer toner or as stabiliser of press ink.

2.2.2 Identification

Information on the identification of dibutyltindichloride is presented in Table 3.

Table 3. Identification of dibutyltindichloride

Chemical name	Dibutyltindichloride
Synonyms	DBT, dibutyltin
CAS-number	683-18-1
EC-number	211-670-0
Structural formula	
Molecular formula	$C_8H_{18}Cl_2Sn$
SMILES code	CCCCSn(Cl)(Cl)CCCC

2.2.3 Physico-chemical properties

Physico-chemical properties of dibutyltindichloride are presented in Table 4. Since the ERLs for DBT in soil and sediment are calculated via equilibrium partitioning, a literature search was performed on sorption parameters of DBT in soils and sediments. Since only two studies with soils were available, also results from studies with sediments were used. The available studies are validated and the reliable endpoints are used to determine the average log K_{oc}. Brief details of the studies are given in Appendix 1. The K_{oc} in ICBR (2009) originates from a citation in the citation based on only two references. Only one of these references could be retrieved and is included in the studies assessed in Appendix 1. Figure 1 shows the correlation between the sorption constant K_d and the fraction organic carbon for the reliable endpoints given in Appendix 1. From this figure, it can be seen that the sorption of a soil is influenced by the faction of organic carbon. Therefore, the derived ERLs for soil and sediment are normalised standard Dutch soil with 10% organic matter and application of equilibrium partitioning, based on the K_{oc}, is considered acceptable.

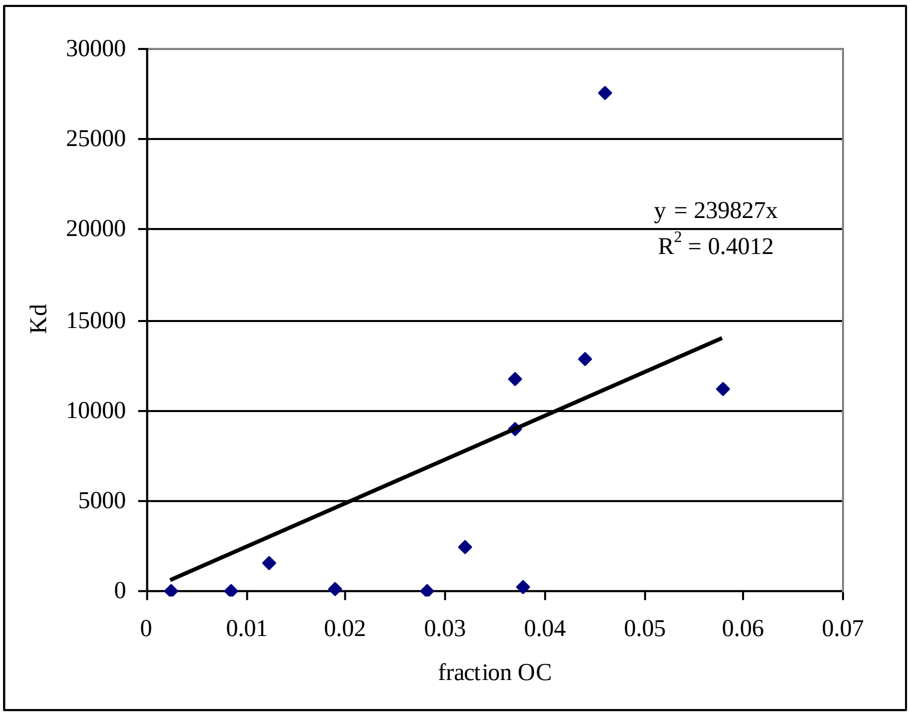


Figure 1. Correlation between sorption constant K_d and the fraction organic carbon

Table 4. Physico-chemical properties of dibutyltindichloride
Bold values are used for ERL derivation.

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	303.85		
Water solubility	[mg/L]	320	20°C, pH 2.5, exp. according to OECD 105	EU-ECB (2000b)
		92	exp. 20°C	US-EPA (2009)
		47.5		EU-ECB (2000b)
pK_a	[-]	n.a.		
Log K_{OW}	[-]	1.5		ICBR (2009)
		1.56 [a]	MlogP	Biobyte (2006)
		1.56	ClogP	Biobyte (2006)
		0.97		EU-ECB (2000b)
Log K_{OC}	[-]	**4.62** [b]	average of 12 log K_{oc} values	see Appendix 1
		5.07		ICBR (2009)
Vapour pressure	[Pa]	**0.16**	exp. 25°C	ICBR (2009); EU-ECB (2000b)
Melting point	[°C]	42	exp.	US-EPA (2009)
Boiling point	[°C]	135	exp.	US-EPA (2009)
Henry's law constant	[Pa.m^3/mol]	1-**1.38**	25°C	ICBR (2009)

[a] It should be noted that in ICBR (2009) calculated log K_{ow} values of 1.89 and 5.33 are reported for DBT-dichloride and DBT-oxide respectively.
[b] Considering the poor correlation between K_d and fraction organic carbon, the log K_{oc} is based on the average log K_{oc} values, rather than the slope of the fitted line.

2.2.4 Behaviour and distribution in the environment

Selected environmental properties of dibutyltin are presented in Table 5.

Table 5. Selected environmental properties of dibutyltin

Parameter	Unit	Value	Remark	Ref.
Hydrolysis half-life	DT50 [d]	-		ICBR (2009)
Degradation	DT50 [d]	122	in soil	RPA (2005)
Photolysis half-life	DT50 [d]	0.6		RPA (2005)
Biodegradability	inherently biodegradable			RPA (2005)
Relevant metabolites	none			ICBR (2009)

2.2.5 Bioconcentration and biomagnification

In ICBR (2009) bioconcentration factors of 12-135 L/kg have been reported. Considering the maximum BCF of 135 L/kg, the risk of secondary poisoning is assessed for dibutyltin.

2.3 Risk limits for water

In ICBR (2009), aquatic risk limits have been derived for dibutyltindichloride. These risk limits are taken over in this report where available, except for human fish consumption.

2.3.1 Aquatic toxicity data

The selected fresh- and marine aquatic toxicity data for freshwater and marine species, reported in ICBR (2009), are given in Table 6 and Table 7. All these studies were evaluated for ICBR (2009) unless stated otherwise; it is however not indicated which were considered valid. Therefore, it is presumed that this involves only the studies adopted in the selected data tables.

Table 6. Dibutyltin: selected freshwater toxicity data for ERL derivation expressed for dibutyltindichloride

Chronic Taxonomic group	$NOEC/EC_{10}$ (µg/L)	Acute Taxonomic group	$L(E)C_{50}$ (µg/L)
Algae		**Algae**	
Scenedesmus obliquus	2.4	*Ankistrodesmus falcatus acicularis*	17400
		Scenedesmus obliquus	89.4 [a]
		Crustacea	
		Daphnia magna	534 [b]
Pisces		**Pisces**	
Oncorhychus mykiss	48.6	*Leuciscus idus*	600
Poecilia reticulata	1800	*Oryzias latipes*	2933 [c]

[a] Geometric mean of 80 and 100 µg/L
[b] Geometric mean of 900 and 317 µg/L
[c] Geometric mean of 5800, 1023, 3249, 981 and 11476 µg/L

Table 7. Dibutyltin: selected toxicity data for marine species for ERL derivation expressed for dibutyltindichloride

Chronic Taxonomic group	$NOEC/EC_{10}$ (µg/L)	Acute Taxonomic group	$L(E)C_{50}$ (µg/L)
Crustacea		**Bacteria**	
Rhithropanopeus harrisii	85 [a]	*Vibrio fischeri*	199 [b]
Mollusca		*Vibrio harveyi*	422 [c]
Mytilus edulis	2	**Algae**	
		Skeletonema costatum	40
		Thalassiosira pseudonana	181

Chronic Taxonomic group	$NOEC/EC_{10}$ (µg/L)	Acute Taxonomic group	$L(E)C_{50}$ (µg/L)
Pisces		**Rotifera**	
Cyprinodon variegatus [d]	453	*Brachionus plicatilis*	625

[a] Geometric mean of 72.1 and 101 µg/L
[b] Geometric mean of 182 and 217 µg/L
[c] Geometric mean of 380, 440 and 450 µg/L
[d] In ICBR (2009) the endpoint for this species was tabulated under freshwater; the experiment is however performed in diluted seawater with a salinity of 15‰. Since the fresh- and saltwater datasets are combined (see below), this does not affect the results.

2.3.2 *Treatment of fresh- and saltwater toxicity data*

In ICBR (2009), it is statistically shown that there is no significant difference between fresh- and saltwater data (p = 0.14 and p = 0.46 for acute and chronic, respectively). Therefore, the two datasets were combined.

2.3.3 *Derivation of the MPC_{water}*

2.3.3.1 Derivation of the $MPC_{water, eco}$

In ICBR (2009), a PNEC for fresh surface water of 0.2 µg/L expressed for dibutyltindichloride has been derived on the basis of the NOEC of 2 µg/L for mollusc with an assessment factor of 10 because chronic data are available for an algae, a crustacean and fish. This value expressed for the dibutyltin cation as 0.15 µg/L is taken over as the $MPC_{fw, eco}$. For the marine environment, the same MPC of 0.2 µg/L expressed for dibutyltindichloride has been derived, using an assessment factor of 10 because toxicity data were available for two specific marine taxonomic groups. This value expressed as 0.15 µg/L for the dibutyltin cation is taken over as the $MPC_{sw, eco}$.

2.3.3.2 Derivation of the $MPC_{water, secpois}$

In ICBR (2009), a quality standard for animals eating aquatic organisms has been calculated of 0.22 µg/L for the dibutyltin cation. The calculated MPC is based on a NOEC of 30 mg/kg_{food} for growth reduction (FH-IME, 2007) from a 90 days oral study with rats. An assessment factor of 90 (resulting in an $MPC_{oral, min}$ of 0.3 mg/kg_{fd}), a BCF of 135 L/kg and an additional assessment factor of 10 has been applied. The reason for the additional assessment factor is unknown. Since this value is higher than the MPCs for fresh and salt surface water based on direct ecotoxicity, these MPCs can be considered to be protective for secondary poisoning.

2.3.3.3 Selection of the MPC_{water}

The $MPC_{water, secpois}$ is higher than the MPCs for fresh and salt surface water, based on direct ecotoxicity; these MPCs can be considered to be protective for secondary poisoning. The MPC_{fw} and MPC_{sw} are 0.15 µg/L.

2.3.4 *Derivation of the $MAC_{water, eco}$*

In ICBR (2009), a PNEC for short-term exposure has been derived by dividing the lowest acute toxicity value of 40 µg/L for an algae, by a factor of 1000. This factor has been used according to Lepper (2005) because dibutyltin has a BCF >100 L/kg and therefore a potential to bioaccumulate, and an additional assessment factor of 10 was applied over the standard assessment factor of 100. The derived value of 0.04 µg/L expressed for dibutyltindichloride was not put forward as final value because it was lower than the PNEC for fresh surface water. Currently, in accordance with the coming new guidance for derivation of

quality standards under the Water Framework Directive, the additional assessment factor of 10 for bioaccumulating substances is not applied anymore because bioaccumulation is not considered relevant for short-term exposure toxicity. Therefore the $MAC_{fw, eco}$ is set in line with the current methodology expressed for the dibutyltin cation at 0.3 μg/L.
For the saltwater environment, also no MAC has been proposed because it was lower than the PNEC. Since the datasets for fresh- and saltwater are combined, the $MAC_{sw, eco}$ is based on the combined dataset with an additional assessment factor of 10 because no acute endpoints are available for specific marine species. The $MAC_{sw, eco}$ is 0.03 μg/L for the dibutyltin cation. However, this value is lower than the $MPC_{sw, eco}$, this is deemed unrealistic. Therefore, the $MAC_{sw, eco}$ is set equal to the $MPC_{sw, eco}$ at 0.15 μg/L.

2.3.5 Derivation of the SRC_{water}

2.3.5.1 Derivation of the $SRC_{water, eco}$

The $SRC_{water, eco}$ is calculated as the geometric mean of the chronic endpoints given in Table 6 and Table 7 and expressed for the dibutyltin cation: 50 μg/L.

2.3.5.2 Derivation of the $SRC_{water, secpois}$

For the $SRC_{eco, oral}$, the NOEC of 30 mg/kg_{food} for growth reduction of rats, as used for the MPC for secondary poisoning, is used as representative for rats. Correction for laboratory feed (assessment factor 3) and correction from subchronic to chronic (assessment factor 3) results in an NOEC for rats of 3.3 mg/kg_{food}. In addition, a LOAEL of 2.2 $mg/kg_{bw}/d$ for the dibutyltin cation is available for maternal food consumption and fetal development of cynomolgus monkeys (macaque) exposed from day 20 to 50 during pregnancy (Ema et al., 2007). This is considered a chronic endpoint. Conversion to food with a factor 20 and after application of an assessment factor of 3 to correct for laboratory feed and a factor 10 to convert from LOAEL to a NOAEL, the NOEC for monkeys is 1.5 mg/kg_{food}. The $SRC_{eco, oral}$ is equal to the geometric mean of the NOEC values for rats and monkeys and is 2.2 mg/kg_{food}. With this value and the BCF of 135 L/kg, the $SRC_{water, secpois}$ is 16 μg/L.

2.3.5.3 Selection of the SRC_{water}

The SRC_{water} is determined by the lowest value, this is the $SRC_{water, secpois}$ of 16 μg/L.

The SRC_{water} is valid for the fresh- and saltwater environment.

2.4 Risk limits for groundwater

The $MPC_{gw, eco}$ and $SRC_{gw, eco}$ are equal to the $MPC_{fw, eco}$ and $SRC_{fw, eco}$ and are 0.15 μg/L and 50 μg/L respectively for the dibutyltin cation.

2.5 Risk limits for sediment

2.5.1 Derivation of the $MPC_{sediment, eco}$

In ICBR (2009) a quality standard for sediment of 23.5 $μg/kg_{dwt}$ (and 51.1 $μg/kg_{wwt}$) has been derived from the PNEC for water using equilibrium partitioning. In this calculation, an additional assessment factor of 10 has been used since the log K_{ow} for DBT-oxide is higher than 5. This assessment factor corrects for other exposures than via (pore)water which should be considered for high K_{ow} values. Calculation of this value in ICBR (2009) does however contain an error since conversion from wet- to dry sediment should give a higher concentration rather than a lower concentration. Application of the additional assessment factor of 10 is considered not necessary since the maximum BCF of 135 L/kg indicated that the contribution of ingestion is not significant. Use of the log K_{oc} value derived in this report (this value is preferred since it is based on endpoints for more (different) soils) results in a value of 0.37 mg/kg_{dwt} for Dutch standard soil.

2.5.2 *Derivation of the $SRC_{sediment, eco}$*

An $SRC_{sediment, eco}$ has not been derived in ICBR (2009); application of equilibrium partitioning on the $SRC_{water, eco}$ provides a value of 123 mg/kg_{dwt} for Dutch standard sediment with 10% OM expressed for the dibutyltin cation. This calculation has been performed with the log K_{oc} derived in this report (see section 2.2.3). The additional assessment factor of 10 as applied in ICBR (2009) for substances with a log K_{ow} > 5 is not applied for the reason given above.

2.6 Risk limits for soil

2.6.1 *Soil toxicity data*

No soil toxicity data are available from the public literature.

2.6.2 *Derivation of the MPC_{soil}*

2.6.2.1 Derivation of $MPC_{soil, eco}$

Since no soil toxicity data are available, the $MPC_{soil, eco}$ is calculated from the $MPC_{fw, eco}$ given above and the K_{oc} value derived in this report using equilibrium partitioning. The calculated $MPC_{soil, eco}$ is 0.37 mg/kg_{dwt} for the dibutylin cation in Dutch standard soil with 10% organic matter.

2.6.2.2 Derivation of the $MPC_{soil, secpois}$

A BCF has been reported higher than 100 L/kg; therefore, secondary poisoning is triggered. An $MPC_{soil, secpois}$ can be calculated from the $MPC_{oral, min}$ of 0.3 mg/kg_{fd} given above with the method as described in Van Vlaardingen and Verbruggen (2007). A BCF for earthworms is not available and the use of a QSAR on the basis of the log K_{ow} is considered not appropriate considering the large difference between the log K_{ow} values of dibutyltindichloride and bioaccumulation characteristics of dibutyltin. Therefore, the use of the BCF for fish of 135 L/kg is considered the best alternative. The calculated $MPC_{soil, secpois}$ is 3.8 mg/kg_{dwt} for the dibutylin cation in Dutch standard soil with 10% organic matter.

2.6.2.3 Selection of the MPC_{soil}

Since the $MPC_{soil, secpois}$ is higher than the $MPC_{soil, eco}$ (more than a factor of 10), it can be considered that the $MPC_{soil, eco}$ is protective for secondary poisoning. Therefore, the MPC_{soil} is set by the $MPC_{soil, eco}$: 0.37 mg/kg_{dwt} for the dibutylin cation in Dutch standard soil with 10% organic matter.

2.6.3 *Derivation of the SRC_{soil}*

2.6.3.1 Derivation of the $SRC_{soil, eco}$

Since no soil toxcitiy data are available, the $SRC_{soil, eco}$ is calculated from the $SRC_{fw, eco}$ given above, using equilibrium partitioning. The calculated $SRC_{soil, eco}$ is 123 mg/kg_{dwt} for the dibutylin cation in Dutch standard soil with 10% organic matter.

2.6.3.2 Derivation of the $SRC_{soil, secpois}$

For the $SRC_{eco, oral}$, the geometric mean of the values for rats and monkeys of 2.2 mg/kg_{food} as determined above is used. With this value, the $SRC_{soil, secpois}$, as calculated with the method as described in Van Vlaardingen and Verbruggen (2007), is 28 mg/kg_{dwt} for Dutch standard soil.

2.6.3.3 Selection of the SRC_{soil}

Since the $SRC_{soil, secpois}$ is lower than the $SRC_{soil, eco}$, the SRC_{soil} will be 28 mg/kg_{dwt} for dibutyltin cation in Dutch standard soil.

2.6.4 *Geometric mean of MPC and SRC*

The geometric mean of the MPC_{soil} and SRC_{soil} is 3.2 mg/kg_{dwt} for the dibutyltin cation. Since this value is based on two different routes of exposure, it is not equivalent to an HC20.

3 Tributyltin

3.1 Data sources

For tributyltin compounds, aquatic ERLs have been derived by the European Commission under the Water Framework Directive (EC, 2005). The ERLs for tributyltin expressed for the TBT-ion are adopted as the ERLs for all tributyltin compounds.

3.2 Substance information

3.2.1 Information on production and use

Tributyltin compounds are being used for wood preservation, antifouling in marine paints and for antifungal action in textiles and industrial water systems. The use of tributyltin as antifouling has been banned since 2003 in the EU (RIVM, 2010, Norway, 2008) and other biocidal use should have ceased before September 2006 (Norway, 2008). Other uses are still allowed and bis(tributyltin)oxide as well as tributyltin chloride are registered under REACH. Further marketing and use restrictions are currently under consideration within the REACH framework (Norway, 2008) and tributyltin is placed on the REACH candidate list for inclusion in Annex XIV (www.echa.europa.eu). This means that only use in closed systems will be allowed.

3.2.2 Identification

Information on the identification of different species of tributyltin presented in EC (2005) are given in the tables below. Details on three different forms of tributyltin are presented, in the environment; all three will become available as the tributyltin-cation.

Table 8. Identification of the tributyltin cation

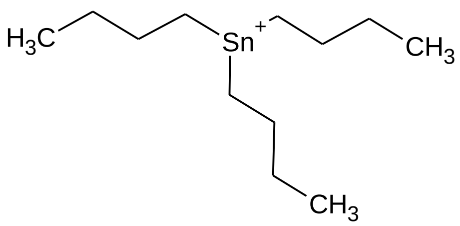
Chemical name	Tributyltin cation
Synonyms	TBT, tri-n-butyltin
CAS-number	36643-28-4
EC-number	-
Structural formula	
Molecular formula	$C_{12}H_{28}Sn$
SMILES code	CCCCSn(CCCC)CCCC

Table 9. Identification of tributyltin hydride

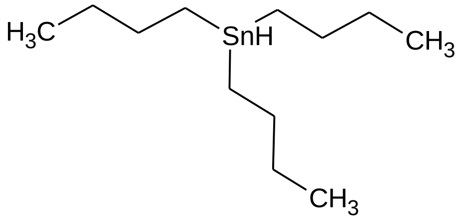
Chemical name	Tributyltin hydride
Synonyms	TBT, tri-n-butyltin hydride
CAS-number	688-73-3
EU-number	211-704-4
Structural formula	
Molecular formula	$C_{12}H_{29}Sn$
SMILES code	CCCCSn(CCCC)CCCC

Table 10. Identification of tributyltin chloride

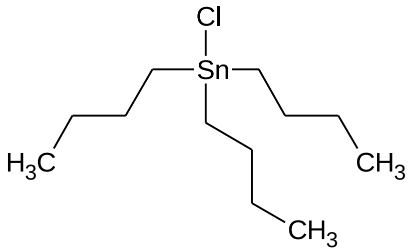
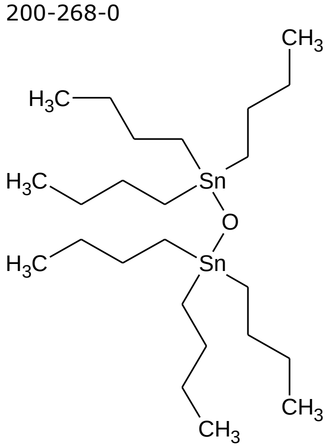
Chemical name	Tributyltin chloride
Synonyms	TBT-Cl, tri-n-butyltinchloride; Tributylchlorostannane
CAS-number	1461-22-9
EC-number	215-958-7
Structural formula	
Molecular formula	$C_{12}H_{28}ClSn$
SMILES code	CCCCSn(Cl)(CCCC)CCCC

Table 11. Identification of bis(tributyltin)oxide

Chemical name	Bis(tributyltin)oxide
Synonyms	TBT, tributyltin oxide
CAS-number	56-35-9
EC-number	200-268-0
Structural formula	
Molecular formula	$C_{24}H_{54}OSn$
SMILES code	CCCCSn(CCCC)(CCCC)OSn(CCCC)(CCCC)CCCC

3.2.3 *Physico-chemical properties*

Physico-chemical properties of different species of tributyltin presented in EC (2005) are summarized in the tables below. Since the ERLs for TBT in sediment are calculated through equilibrium partitioning and the K_{oc} in EC (2005) originates from only two unavailable studies, a literature search is performed on sorption parameters of TBT in soil and sediments. Like the case for DBT, the studies are validated and the reliable endpoints are used to determine the average log K_{oc}. Brief details if the studies are given in Appendix 1. Figure 2 shows the correlation between the sorption constant K_d and the fraction organic carbon for the endpoints for tributyltin given in Appendix 1. From this figure, it can be seen that the sorption of a soil to some extent is influenced by the faction of organic carbon. Therefore, the derived ERLs for soil and sediment are normalised standard Dutch soil with 10% organic matter, and application of equilibrium partitioning, based on the K_{oc}, is considered acceptable.

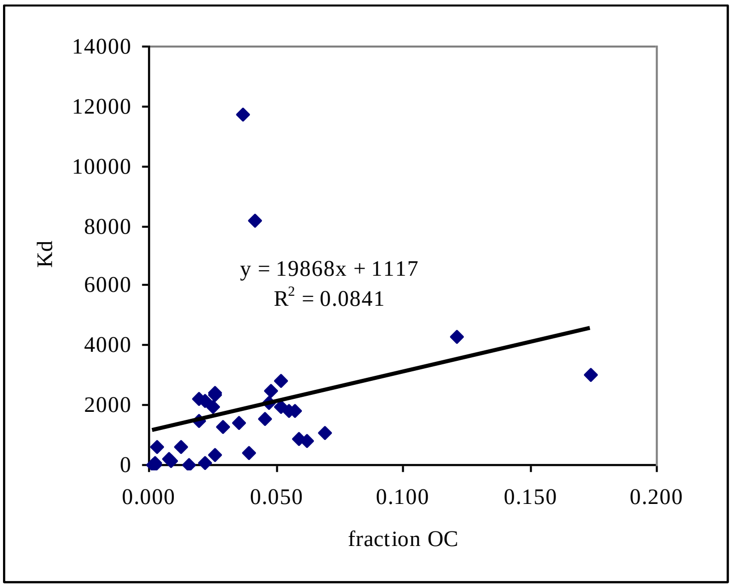


Figure 2. Correlation between sorption constant K_d and the fraction organic carbon

Table 12. Physico-chemical properties of tributyltin hydride

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	291.09		
Water solubility	[mg/L]	5.3	25°, estimated from log K_{ow} of 4.00	US EPA (2009)
pK_a	[-]			
Log K_{OW}	[-]	4.00	estimated ClogP	Biobyte (2006)
		7.35	estimated	US EPA (2009)
		4.1	experimental	SRC (2011)
Log K_{OC}	[-]	n.a.	see TBT-Cl	
Vapour pressure	[Pa]	766.6	experimental, 25°C	US EPA (2009)
		5.3	estimated, 25°C	US EPA (2009)
Melting point	[°C]	80	experimental	US EPA (2009)
Boiling point	[°C]	250	estimated	US EPA (2009)
		122.5-113.5		HSDB (2005)
Henry's law constant	[Pa.m^3/mol]	42 x 10^3	25°C, calculated: mw x vp/ws	

Table 13. Physico-chemical properties of tributyltin chloride

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	325.51		
Water solubility	[mg/L]	17	experimental, 20°C	US EPA (2009)
pK_a	[-]			
log K_{OW}	[-]	4.25	estimated ClogP	Biobyte (2006)
		4.25	experimental MlogP	Biobyte (2006)
		4.76	experimental	US EPA (2009); HSDB (2005)
Log K_{OC}	[-]	**4.5**	average of 33 log K_{oc} values	see Appendix 1
		2.5-6.2	range for two references, original studies not available, the actual species of TBT tested is unclear	EC (2005); Hillenbrand et al. (2006)
Vapour pressure	[Pa]	48.5	estimated, 25°C	US EPA (2009)
		30	estimated, 20°C	US EPA (2009)
Melting point	[°C]	53	experimental	US EPA (2009)
Boiling point	[°C]	193	experimental	US EPA (2009)
		171-173		HSDB (2005)
Henry's law constant	[Pa.m^3/mol]	574	20°C, calculated: mw x vp/ws	

* This value of 4.5 is used where necessary since this value is located within the range as reported in EC (2005) and is based on a large number of studies. Considering the poor correlation between K_d and fraction OC, the log K_{oc} is based on the average log K_{oc} values, rather than the slope of the fitted line.

Table 14. Physico-chemical properties of bis(tributyltin)oxide

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	596.12		
Water solubility	[mg/L]	19.5	Experimental, temperature unknown	US EPA (2009)
		4		HSDB (2005)
		18-61.4		EC (2005)
		0.75	pH 6.6	EC (2005), Hillenbrand et al. (2006)
		31	pH 8.1	EC (2005)
		4	pH 7, 20°C)	Hillenbrand et al.(2006), Norway (2008)
pK_a	[-]			
Log K_{OW}	[-]	4.38	estimated ClogP	Biobyte (2006)
		3.84	experimental	US EPA (2009)
		4.05	estimated	US EPA (2009)
		3.85		EC (2005)
		3.2-3.8		EC (2005)
Log K_{OC}	[-]	n.a.	see TBT-Cl	
Vapour pressure	[Pa]	0.001	20°C, experimental	US EPA (2009)
Melting point	[°C]	< -45		EU-ECB (2000a)
Boiling point	[°C]	220-230		EU-ECB (2000a)
		173		EU-ECB (2000a)
		180		EU-ECB (2000a)
Henry's law constant	[Pa.m^3/mol]	0.15	20°C, calculated with water solubility of 4 mg/L: mw x vp/ws	

* In EC (2005), also a value of 30 mg/L for a pH of 2.6 is reported. This value seems not realistic for this pH. In the latest version of the original reference (Hillenbrand et al., 2006); this value is not included anymore.

3.2.4 *Behaviour and distribution in the environment*

Selected environmental properties of tributyltin are presented in Table 15.

Table 15. Selected environmental properties of tributyltin

Parameter	Unit	Value	Remark	Ref.
Hydrolysis half-life	DT50 [d]		no information	
Degradation	DT50 [d]	20-35	in freshwater	Hillenbrand (2006)
Photolysis half-life	DT50 [d]		no information	
Biodegradability	not readily biodegradable			US EPA (2009)
Relevant metabolites	none			

Bis(tributyltin) oxide has been considered as a PBT substance and fulfils the PBT critera (Norway, 2008), and is placed on the REACH candidate list for inclusion in Annex XIV (www.echa.europa.eu). Since this substance transforms to the tributyltin cation in the environment, it can be concluded that the TBT-cation also fulfils the PBT criteria.

3.2.5 *Bioconcentration and biomagnification*

In EC (2005), bioconcentration factors for fish are reported of 2600 and 52000 L/kg. The latter value is for liver only. For molluscs, values ranging from 1000 to 11400 L/kg are reported, and for a crustacean a value of 500-4400 L/kg is reported. In EC (2005), a BCF of 6000 L/kg is used to assess the risk of secondary poisoning and human health through fish consumption. In Van Herwijnen et al. (2012), it is stated that TBT does not biomagnify. It should be noted that the BCF for triphenyltin is determined to be 3500 L/kg (Van Herwijnen et al., 2012). This value is lower than that for TBT; this is in contradiction with, as is reported in Van Herwijnen et al. (2012), that the biomagnification potential of triphenyltin is higher than for TBT. Therefore the value of 6000 L/kg for TBT is considered very high and should be seen as a worst case estimate.

3.3 Risk limits for water

In EC (EC, 2005), aquatic risk limits have been derived for the tributyltin ion. These risk limits are taken over in this report where applicable.

3.3.1 *Aquatic toxicity data*

The fresh- and saltwater toxicity data selected in EC (2005) are given in Table 16 and Table 17 respectively.

Table 16. Tributyltin: selected freshwater toxicity data for ERL derivation

Chronic Taxonomic group	NOEC/EC10 (µg/L)	**Acute** Taxonomic group	L(E)C/50 (µg/L)
		Cyanobacteria	
		Anabaena flos aquae	13
Algae		**Algae**	
Chlorella pyrenoidosa	18	*Ankistrodesmus falcatus*	5
Pseudokirchneriella subcapitata	4	**Macrophyta**	
		Azolla filiculoides	8.3
Mollusca		*Lemna minor*	30.8
Lymnea stagnalis	0.32	**Annelida**	
		Tubifex tubifex	0.1
Crustacea		**Crustacea**	
Daphnia magna	0.16	*Daphnia magna*	0.03

Chronic Taxonomic group	NOEC/EC10 (µg/L)	Acute Taxonomic group	L(E)C/50 (µg/L)
Insecta		**Insecta**	
Hexagenia sp.	0.5	*Chironomus plumosus*	0.05
Pisces		**Pisces**	
Oncorhynchus mykiss	0.04	*Ictalurus punctatus*	12
Pimephales promelas	0.17	*Oncorhynchus mykiss*	1.28
Poecilia reticula	0.01	*Phoxinus phoxinus*	0.69
		Amphibia	
		Rana temporaria	1.65

Table 17. Tributyltin: selected saltwater toxicity data for ERL derivation

Chronic Taxonomic group	NOEC/EC10 (µg/L)	Acute Taxonomic group	L(E)C/50 (µg/L)
Algae		**Algae**	
Dunaliella tertiolecta	0.05	*Enteromorpha intestinalis*	0.027
Mollusca		*Skelotonema costatum*	0.33
Buccinum undatum	0.0028	**Mollusc**	
Crassostrea gigas	0.005	*Crassostrea virginica*	0.13
Mercanaria mercanaria	0.0024		
Mytilus edulis	0.006		
Nucella lapillus	0.001		
Nucella lima	0.0064		
Saccostrea commercialis	0.005		
Annelida			
Neanthes arenaceodentata	0.05		
Crustacea		**Crustacea**	
Acartia tonsa	0.1	*Acartia tonsa*	0.015*
Eurytemora affinis	0.01		
Gammarus oceanicus	0.3		
Palaemonetes pugio	0.033		
Echinodermata			
Ophioderma brevispina	0.01		
Pisces		**Pisces**	
Cyprinodon variegatus	0.34	*Solea solea*	2.1
Gasterosteus aculeatus	0.1		

* In EC (2005) a value of 0.0015 µg/L is tabulated, but in the text a value of 0.015 is used to derive the MAC-QS. Verification in the original reference revealed that the latter value is the correct one.

3.3.2 *Treatment of fresh- and saltwater toxicity data*

In EC (2005), it is reported that there is no difference between fresh- and saltwater data, and the two datasets were combined. From Table 16 and Table 17 can however be seen that a difference between the two datasets is not unlikely ($p = 0.076$). Also, at the level of taxonomic groups, there seems to be a difference, for example for molluscs and algae.

3.3.3 *Derivation of the MPC_{water}*

3.3.3.1 Derivation of the $MPC_{water, eco}$

In EC (2005), a quality standard for fresh surface water of 0.2 ng/L has been derived on the basis of the HC5 of a Species Sensitivity Distribution (SSD) with an assessment factor of 4. For this SSD, it has been considered that plants are missing, but the quality standard derived through this method is preferred over one derived through the assessment factor method. The quality standard from the SSD is taken over as the $MPC_{fw, eco}$. For the saltwater environment, the same quality standard of 0.2 ng/L has been derived because a comprehensive data set on marine species is available. This quality standard is taken over as the $MPC_{sw, eco}$.

3.3.3.2 Derivation of the $MPC_{water, secpois}$

In EC (2005), a quality standard for animals eating aquatic organisms has been calculated of 38 ng/L. The calculated quality standard is based on a reproduction NOAEL of 0.34 mg/kg_{bw}/d for rats from a long term study, a conversion factor of 20, an assessment factor of 30 (resulting in an $MPC_{oral, min}$ of 0.23 mg/kg_{fd}) and a BCF of 6000 L/kg. The value of 38 ng/L is taken over as the $MPC_{fw, secpois}$. The BMF_2 for the marine environment is set at 1; therefore, this value is also valid for the marine environment.

3.3.3.3 Selection of the MPC_{water}

The MPC_{fw} and MPC_{sw} are determined by the lowest value: 0.2 ng/L.

3.3.4 Derivation of the $MAC_{water, eco}$

In EC (2005), a MAC-QS has been derived by dividing the lowest acute toxicity value, of 0.015 µg/L for *Acartia tonsa*, by a factor 10. This factor was used because the large dataset on freshwater and marine taxonomic groups shows that the other groups do not have a higher acute sensitivity to TBT-compounds. The dataset does however fulfil the requirements to perform an SSD:

- Fish: *Ictalurus punctatus*
- A second family of fish: *Oncorhynchus mykiss* and others
- A crustacean: *Daphnia magna* and *Acartia tonsa*
- An insect: *Chironomus plumosus*
- A family in a phylum other than Arthropoda or Chordata: *Crassostrea virginica*
- A family in any order of insect or any phylum not already represented: *Anabaena flos-aquae*
- Algae: *Ankistrodesmus falcatus* and others
- Higher plants: *Lemna gibba*

The use of an SSD is preferred since all data are involved. The SSD determined with ETX (Van Vlaardingen et al., 2004) is shown in Figure 3. The calculated HC5 is 0.010 µg/L, with a two sided 90% confidence interval of 0.0013 - 0.041 mg/L. The goodness of fit is accepted at all levels by the three statistical tests available in the program.

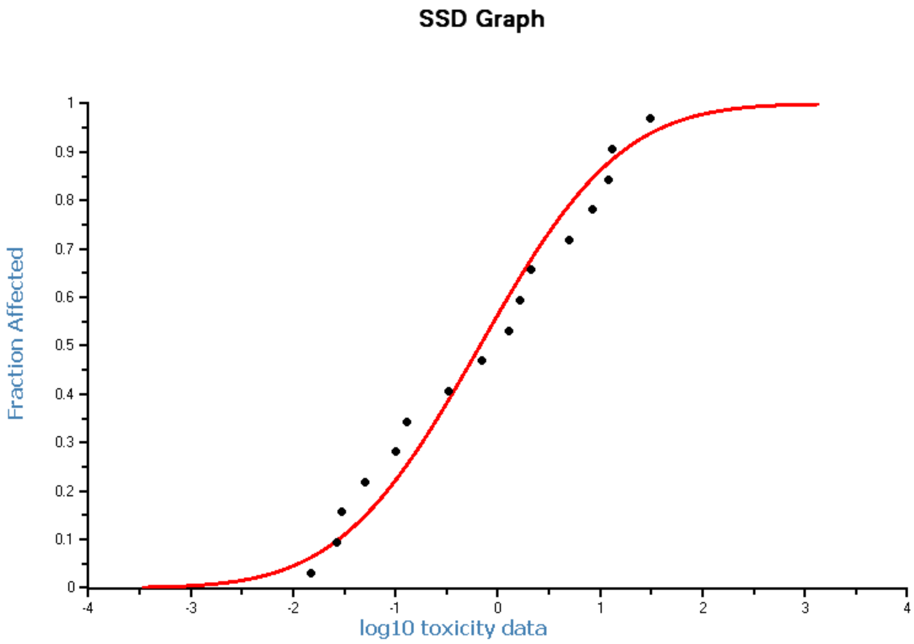


Figure 3 Species Sensitivity Distribution for tributyltin (acute data)

Nevertheless, for freshwater, the value of 1.5 ng/L derived in EC (2005), is taken over as the $MAC_{fw,\ eco}$. For the saltwater environment no MAC has been derived in EC (2005) and the $MAC_{sw,\ eco}$ will be based on the SSD. Since acute toxicity data are available for one specific marine species (*Crassostrea virginica*), the $MAC_{sw,\ eco}$ is derived from the HC5 by an assessment factor of 50 at 0.2 ng/L.

3.3.5 *Derivation of the SRC_{water}*

3.3.5.1 Derivation of the $SRC_{water,\ eco}$

The $SRC_{water,\ eco}$ is determined by the HC50 of 46 ng/L from the SSD.

3.3.5.2 Derivation of the $SRC_{water,\ secpois}$

For the $SRC_{eco,\ oral}$, the NOAEL of 0.34 mg/kg_{bw}/d for rats from a long term study, as used for the MPCs for secondary poisoning, is used as representative for rats. Conversion to food (factor 20) and correction for laboratory feed (assessment factor 3) results in an NOEC for rats of 2.3 mg/kg_{food}. In addition, endpoints for two more species are available.
For mice, a NOAEL of 0.38 mg/kg_{bw}/d for the tributyltin cation is available for testicular sperm head counts in mice orally exposed to TBT-O for 4 weeks during the premature period (Kumasaka et al., 2002). In contradiction, Yan et al. (2009) and Chen et al. (2008) reported much lower NOAELs of < 0.45 µg/kg_{bw} for the tributyltin cation from a similar test with mice exposed to TBT-Cl once every three days. Apart from the different test substance, there is also a difference in the vehicle used. Kumasaka et al. (2002) used a solution in 0.2% ethanol while the other two studies used a solution with an ethanol: 0.85% sodium chloride ratio of 1:10 (v:v). In the case of Kumasaka et al. (2002), it can be questioned if the ethanol concentration was high enough to enable a full

solubility of the TBT-O. Presuming a vehicle volume of 5 μl/g as used in the other two studies, the doses would exceed the water solubility of TBT-O at a neutral pH, and at a lower pH as in the stomach the solubility will be even lower. If the substance would not be fully dissolved, this could influence the uptake and actual exposure of the mice tested. Considering this and the fact that a different substance is tested, the endpoint from Yan et al. (2009) and Chen et al. (2008) is selected. This is considered a chronic endpoint. Conversion to food with a factor 8.3 and after application of an assessment factor of 3 to correct for laboratory feed, a correction for daily exposure (factor 3) and an assessment factor of 10 to correct from LOAEL to NOAEL, the NOEC for mice is 0.04 μg/kg_{food}. For mice, a second NOEC of 19.5 mg/kg_{food} expressed for the TBT-cation is available for maternal toxicity of mice exposed during pregnancy (Baroncelli et al., 1990). This is also considered a chronic endpoint. Application of an assessment factor of 3 to correct for laboratory feed results in an NOEC of 6.5 mg/kg_{food}. Penza et al. (2011) reported a not-dose-related but significant effect on the fat/bodyweight ratio of mice exposed through diet at a concentration of 5 μg/kg_{diet} for a period of three months. Since this effect is not dose-related (higher and lower concentrations showed no significant effects), it is unclear if this effect is caused by tributyltin or just an artefact. The first value for mice is most critical and will be used for the $SRC_{water, secpois}$. It should be noted that the fact that the selected endpoint for mice is much lower than that for rats as used for the $MPC_{water, secpois}$ indicates that the $MPC_{water, secpois}$ is probably underprotecting. This also involves the ADI as used in EC (2005). Furthermore a chronic NOEC of 24 mg/kg_{food} is available for hatchability of *Coturnix coturnix* eggs of which the parents were exposed for six weeks in the egg laying period (Coenen et al., 1992). Correction for laboratory feed results in an SRC_{oral} for birds of 8 mg/kg_{food}. The geometric mean of the values for rats, mice and birds is 0.09 mg/kg_{food}. With this value and the BCF of 6000 L/kg, the $SRC_{water, secpois}$ is 15 ng/L. Considering the fact that this value is based on a worst-case BCF, this value can also be considered worst-case. A more realistic approach would be to use the fish BCF for triphenyltin since this compound is considered to have a higher bioaccumulation potential than TBT. With the BCF of 3500 L/kg for triphenyltin, the $SRC_{water, secpois}$ is 26 ng/L. The latter value is preferred.

3.3.5.3 Selection of the SRC_{water}

The SRC_{water} is determined by the lowest value; this is the $SRC_{water, secpois}$ of 26 ng/L.

The SRC_{water} is valid for the fresh- and saltwater environment.

3.4 Risk limits for groundwater

The $MPC_{gw, eco}$ and $SRC_{gw, eco}$ are equal to the $MPC_{fw, eco}$ and $SRC_{fw, eco}$ and are 0.2 ng/L and 46 ng/L respectively.

3.5 Risk limits for sediment

3.5.1 Derivation of the $MPC_{sediment, eco}$

In EC (2005), a quality standard for sediment of 0.02 μg/kg_{dwt} has been derived from the quality standard for fresh surface water using equilibrium partitioning and a log K_{oc} of 3.0. For Dutch standard soil with 10% OM, this value is 0.01 μg/kg_{dwt}. Since this log K_{oc} is relatively low compared to the range of log K_{oc} values tabulated in Appendix 1, the $MPC_{sediment, eco}$ should be seen as a worst case estimate.

3.5.2 *Derivation of the $SRC_{sediment, eco}$*

An $SRC_{sediment, eco}$ has not been derived in EC (2005); application of equilibrium partitioning on the $SRC_{water, eco}$ provides a value of 27 μg/kg$_{dwt}$ for Dutch standard soil with 10% OM. This calculation has been performed with the log K_{oc} of 4.0 derived in this report.

3.6 Risk limits for soil

3.6.1 *Soil toxicity data*

Selected soil toxicity data are given in Table 18; details on these endpoints are tabulated in Appendix 2.

Table 18. Tributyltin: selected soil toxicity data for ERL derivation

Chronic		**Acute**	
Taxonomic group	**NOEC/EC10 (mg/kg$_{dwt}$)**	**Taxonomic group**	**L(E)C/50 (mg/kg$_{dwt}$)**
Microbial processes		**Microbial processes** [e]	
respiration/dehydrogenase/ ATP content	12	Potential nitrification	65
		Potential nitrification	221
		Potential nitrification	279
Macrophyta		**Macrophyta**	
		Avena sativa	1395 [f]
Brassica rapa	37.4 [a]	*Brassica rapa*	63 [g]
Annelida		**Annelida**	
Eisenia fetida	7.2 [b]	*Eisenia fetida*	7.9 [h]
Eisenia andrei	2.4 [c]		
Collembola			
Folsomia candida	55.6 [d]		

[a] Geometric mean of EC10 values of 205.2, 9.5, 26.1, 9.3, 72.0, 137.8, 9.0 and 91.3 mg/kg$_{dwt}$ for Dutch standard soil

[b] Geometric mean of 7.6, 10.3 and 4.8 mg/kg$_{dwt}$ for Dutch standard soil

[c] Most sensitive endpoint reproduction; geometric mean of 4.7, 5.1, 1.1, 0.2, 5.2, 1.0, 6.1, 8.7 and 2.1 mg/kg$_{dwt}$ for Dutch standard soil

[d] Lowest geometric mean of 70.2, 26.4, 29.1, 72.6, 61.8, 110.4, 18.2, 89.9, 209.6 and 30.6 mg/kg$_{dwt}$ for mortality expressed for Dutch standard soil

[e] Endpoints for microbial processes derived from tests with different soils are considered as endpoints from different species, considering the different microbial populations present in the different soils

[f] Geometric mean of 1159, 1907 and 1227 mg/kg$_{dwt}$ for Dutch standard soil

[g] Geometric mean of 64, 55 and 70 mg/kg$_{dwt}$ for Dutch standard soil

[h] Geometric mean of 13.5 and 4.6 mg/kg$_{dwt}$ for Dutch standard soil

3.6.2 *Derivation of the $MPC_{soil,}$*

3.6.2.1 Derivation of the $MPC_{soil, eco}$

Chronic soil toxicity data are available for producers (*Brassica rapa*), consumers (*Eisenia* sp. and *Folsomia candida*) and bacterial processes. With chronic data representing three trophic levels, an assessment factor of 10 can be applied to lowest value of 2.4 mg/kg. This results in an $MPC_{soil, eco}$ of 0.24 mg/kg_{dwt} for Dutch standard soil with 10% organic matter.

3.6.2.2 Derivation of the $MPC_{soil, secpois}$

A BCF has been reported higher than 100 L/kg therefore secondary poisoning is triggered. An $MPC_{oral, min}$ can be detrmined from the lowest NOAEL of < 0.45 $\mu g/kg_{bw}$ for mice given in Section 3.3.5.2. This value can be considered a chronic LOAEL. Conversion to food with a factor 8.3 and after application of an assessmentfactor of 10 to correct from LOAEL to NOAEL, correction for daily exposure (factor 3) and an assessmentfactor of 30 gives an $MPC_{oral, min}$ of 0.004 $\mu g/k_{food}$. From this value, an $MPC_{soil, secpois}$ can be calculated with the method as described in Van Vlaardingen and Verbruggen (2007). A BCF for earthworms is not available and the use of a QSAR on the basis of the log K_{ow} is considered not appropriate considering the bioaccumulation characteristics of TBT. Therefore, the use of the BCF for fish is considered the best alternative. The K_{ow} value used was 4.06 as it was the average of the experimental values for the three TBT-species given in section 3.2.3. The Henry's law constant used was 106 $Pa/m^3/mol$ as the geometric mean of the values for the three TBT-species. With the log K_{oc} value of 4.5 and the worst case BCF of 6000 L/kg, the calculated $MPC_{soil, secpois}$ is 1.4 ng/kg_{dwt} for Dutch standard soil with 10% organic matter. This value is much lower than the $MPC_{soil, eco}$ of 0.24 mg/kg_{dwt}. Considering the fact that this value is based on a worst-case BCF, this value can also be considered worst-case. A more realistic approach would be to use the fish BCF for triphenyltin since this compound is considered to have a higher bioaccumulation potential than TBT. With the BCF of 3500 L/kg for triphenyltin, the $MPC_{soil, secpois}$ is 2.3 ng/kg_{dwt} for Dutch standard soil with 10% organic matter. The latter value is preferred.

3.6.2.3 Selection of the MPC_{soil}

Since the worst-case $MPC_{soil, secpois}$ is lower than the $MPC_{soil, eco}$, the first will set the MPC_{soil} at 2.3 ng/kg_{dwt} for Dutch standard soil with 10% organic matter.

3.6.3 Derivation of the SRC_{soil}

3.6.3.1 Derivation of the $SRC_{soil, eco}$

The $SRC_{soil, eco}$ is calculated as the geometric mean of the chronic toxicity data in Table 18. The $SRC_{soil, eco}$ is 13 mg/kg_{dwt} for Dutch standard soil with 10%organic matter.

3.6.3.2 Derivation of the $SRC_{soil, secpois}$

For the $SRC_{eco, oral}$, the geometric mean of the values for rats, mice and birds of 0.09 mg/kg_{food} as determined above is used for calculation of the $SRC_{soil, secpois}$. With use of the log K_{oc} value of 4.5 and a fish BCF of 6000 L/kg, the calculated $SRC_{soil, secpois}$ would be 31 $\mu g/kg_{dwt}$ for Dutch standard soil with 10% organic matter. Considering the use of the worst-case BCF, this value should also be seen as worst-case. A more realistic approach would be to use the fish BCF for triphenyltin since this compound is considered to have a higher bioaccumulation potential than TBT. With the BCF of 3500 L/kg for triphenyltin, the $SRC_{soil, secpois}$ is 52 $\mu g/kg_{dwt}$ for Dutch standard soil with 10% organic matter. The latter value is preferred.

3.6.3.3 Selection of the SRC_{soil}

The SRC_{soil} is set by the lowest value, this is the $SRC_{soil, secpois}$ of 52 $\mu g/kg_{dwt}$ for Dutch standard soil with 10% organic matter.

3.6.4 Geometric mean of the MPC and SRC

The geometric mean of the MPC_{soil} and SRC_{soil} is 0.35 μg/kg_{dwt}.

4 Triphenyltin

4.1 Data sources

Triphenyltin compounds are triphenyl derivatives of tetravalent tin. They are lipophilic and have low solubility in water. Since triphenyltin compounds are believed to dissociate in the environment and remain unchanged, data available for all triphenyltin compounds (triphenyltin chloride, -acetate, -hydroxide) are evaluated. The ERLs will be expressed in concentration of the dissociated cation. In Van Herwijnen et al. (2012), aquatic risk limits have been derived for triphenyltin. These risk limits are adopted in this report where applicable.

4.2 Substance information

4.2.1 Information on production and use

Triphenyltin compounds have been used extensively as algicides and molluscicides in antifouling products since the 1960s. Use of triorganotins in antifouling paints has been restricted in many countries because of their catastrophic effects on the oyster industry and more general effects on the aquatic ecosystem. Triphenyltin is used as a non-systemic fungicide with mainly protective action.

4.2.2 Identification

Information on the identification of different species of triphenyltin are presented in the tables below.

Table 19. Identification of triphenyltin

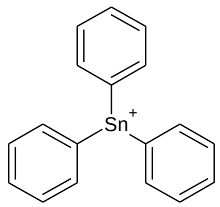
Chemical name	Triphenyltin
Synonyms	Fentin, TPT
Structural formula	
Molecular formula	$C_{18}H_{15}Sn$
SMILES code	c1ccccc1[Sn+](c2ccccc2)c3ccccc3

Table 20. Identification of triphenyltin chloride

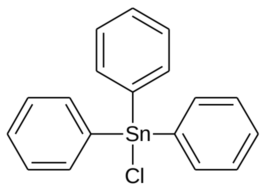
Chemical name	Triphenyltin chloride
Synonyms	Fentin chloride, TPTCl
CAS number	639-58-7
EC number	211-358-4
Structural formula	
Molecular formula	$C_{18}H_{15}SnCl$
SMILES code	Cl[Sn](c1ccccc1)(c2ccccc2)c3ccccc3

Table 21. Identification of triphenyltin hydroxide

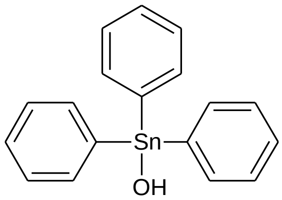
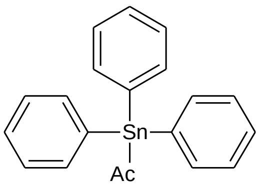
Chemical name	Triphenyltin hydroxide
Synonyms	Fentin hydroxide, TPTH
CAS number	76-87-9
EC number	200-990-6
Structural formula	
Molecular formula	$C_{18}H_{16}SnO$
SMILES code	O[Sn](c1ccccc1)(c2ccccc2)c3ccccc3

Table 22. Identification of triphenyltin acetate

Chemical name	Triphenyltin acetate
Synonyms	Fentin acetate, TPTAc
CAS number	900-95-8
EC number	212-984-0
Structural formula	
Molecular formula	$C_{20}H_{18}O_2Sn$
SMILES code	O=C(C)O[Sn](c1ccccc1)(c2ccccc2)c3ccccc3

4.2.3 *Physico-chemical properties*

Physico-chemical properties of triphenyltin are presented in the following tables for different ionic forms.

Table 23. Physico-chemical properties of triphenyltin chloride
Bold values are used for ERL derivation.

Parameter	**Unit**	**Value**	**Remark**	**Ref.**
Molecular weight	[g/mol]	385.5		HSDB (2005)
Water solubility	[mg/L]	40	20°C	HSDB (2005)
		1.2	10°C, pH 7.5, distilled water*	Inaba et al. (1995)
		0.6	10°C, pH 7.5, seawater*	Inaba et al. (1995)
		0.99	estimated from log K_{ow} of 4.19, 25°C	US EPA (2009)
		1	25°C, from experimental database	US EPA (2009)
		0.078	estimated from fragments	US EPA (2009)
pK_a	[-]	n.a.		
Log K_{OW}	[-]	3.56	estimated - ClogP	Biobyte (2006)
		4.19	experimental - MlogP	Biobyte (2006)
		4.19		HSDB (2005)
Log K_{OC}	[-]	3.89	Experimental calculated from Freundlich log K_d of 1.81 and f_{om} of 1.43%, 1/n = 0.793	Sun et al. (1996)
		3.5	QSAR Sabljic hydrophobics	Van Vlaardingen and Verbruggen (2007)
		5.7	MCI method	US EPA (2009)
		3.6	K_{ow} method	US EPA (2009)
		5.09; 4.73	Laboratory experiment with field sediment; calculated from log K_d and %oc	Berg et al. (2001)

Parameter	Unit	Value	Remark	Ref.
		4.94; 5.37	Field measurements with contam. sediment; calculated from log K_d and %oc	Berg et al. (2001)
Vapour pressure	[mPa]	0.8	estimated, 25°C	HSDB (2005), US EPA (2009)
		0.37	estimated, 20°C	US EPA (2009)
Melting point	[°C]	103.5		HSDB (2005)
Boiling point	[°C]	240	at 1.8 kPa	HSDB (2005)
Henry's law constant	[Pa.m^3/mol]	0.0036	MW x VP/WS, calculated with values for 20°C	Van Vlaardingen and Verbruggen (2007)
		0.3	MW x VP/WS, calculated with values for 25°C	Van Vlaardingen and Verbruggen (2007)

* The solubility is triphenyltin chloride is dependent on the salinity, the pH and the temperature of the water.

Table 24. Physico-chemical properties of triphenyltin hydroxide
Bold values are used for ERL derivation.

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	367.0		HSDB (2005)
Water solubility	[mg/L]	1.2	20°C	HSDB (2005)
		4.72	estimated from log K_{ow} of 3.53, 25°C	US EPA (2009)
		0.4	from experimental database, 25°	US EPA (2009)
		13.8	estimated from fragments	US EPA (2009)
		1.6	± 0.2; determined with saturator system	Jarvinen et al. (1988)
		1		Vogue et al. (1994)
pK_a	[-]	5.20		Biobyte (2006)
Log K_{OW}	[-]	3.50	estimated – ClogP	Biobyte (2006)
		3.53	experimental - MlogP	Biobyte (2006)
		3.53		HSDB (2005)
Log K_{OC}	[-]	4.4		Vogue et al. (1994)
		3.5		Footprint (2011)
		3.0	QSAR Sabljic hydrophobics	Van Vlaardingen and Verbruggen (2007)
		5.7	MCI method	US EPA (2009)
		3.1	K_{ow} method	US EPA (2009)
Vapour pressure	[mPa]	0.047	25 °C	HSDB (2005)
Melting point	[°C]	119		HSDB (2005)
Boiling point	[°C]	n.a.		
Henry's law constant	[Pa.m^3/mol]	0.043	MW x VP/WS, 25°C	Van Vlaardingen and Verbruggen (2007)

Table 25. Physico-chemical properties of triphenyltin acetate
Bold values are used for ERL derivation.

Parameter	Unit	Value	Remark	Ref.
Molecular weight	[g/mol]	409.0		Tomlin (2002)
Water solubility	[mg/L]	9	20°c, pH 5	Tomlin (2002)
		0.71	estimated from log K_{ow} of 4.19, 25°C	US EPA (2009)
		9	from experimental database, 20°C	US EPA (2009)
		0.29	estimated from fragments	US EPA (2009)
pK_a	[-]	n.a.		
Log K_{OW}	[-]	3.46	ClogP	Biobyte (2006)
		3.43		Tomlin (2002)
Log K_{OC}	[-]	3.3		Footprint (2011)
		2.9	QSAR Sabljic hydrophobics	Van Vlaardingen and Verbruggen (2007)
		4.9	MCI method	US EPA (2009)
		2.6	K_{ow} method using log K_{ow} of 3.43	US EPA (2009)

Parameter	Unit	Value	Remark	Ref.
Vapour pressure	[mPa]	1.9	60°C	Tomlin (2002)
		0.038	estimated, 20°C	US EPA (2009)
Melting point	[°C]	122-123		Tomlin (2002)
Boiling point	[°C]	n.a.		
Henry's law constant	[Pa.m^3/mol]	0.0017	MW x VP/WS, 20°C	Van Vlaardingen and Verbruggen (2007)

4.2.4 *Behaviour and distribution in the environment*

Selected environmental properties of triphenyltin are presented in Table 8.

Table 26. Selected environmental properties of triphenyltin

Parameter	Unit	Value	Remark	Ref.
Hydrolysis half-life	DT50 [h]	0.07	triphenyltin acetate, 20°C, pH 7	Footprint (2011)
		30	triphenyltin hydroxide, 20°C, pH 7	Footprint (2011)
Photolysis half-life	DT50 [h]	18	triphenyltin hydroxide, pH 7	Footprint (2011)
Readily biodegradable		No		US EPA (2009)
Relevant metabolites				

In water, both triphenyltin acetate and triphenyltin chloride hydrolyze to triphenyltin hydroxide (HSDB, 2005). For the derivation of MPCs for the water and sediment compartment, the physico-chemical properties of triphenyltin hydroxide are therefore preferred.

4.2.5 *Bioconcentration and biomagnification*

In Van Herwijnen et al. (2012) a BCF value of 3500 L/kg is selected for triphenyltin. The selected BMF1 and BMF2 are 3.7 and 1 respectively.

4.3 Risk limits for water

In Van Herwijnen et al. (2012), aquatic risk limits have been derived for triphenyltin. These risk limits are taken over in this report where available.

4.3.1 *Aquatic toxicity data*

The fresh- and saltwater toxicity data selected in Van Herwijnen et al. (2012) are given in Table 27 and Table 28 respectively.

Table 27. Triphenyltin: selected freshwater toxicity data for ERL derivation for the triphenyltin ion

Chronic[a] **Taxonomic group/***species*	**NOEC/EC10 (µg/L)**	**Acute**[a] **Taxonomic group/***species*	**L(E)C50 (µg/L)**
Algae		**Algae**	
Scenedesmus obliquus	2.3	*Scendesmus obliquus*	27
Scenedesmus vacuolatus	44.5	*Scenedesmus vacuolatus*	102
Macrophyta		**Macrophyta**	
Lemna minor	0.9 [b]	*Lemna minor*	12 [b]
Lemna polyrhiza	2.2 [c]	*Lemna polyrhiza*	24 [c,b]
		Platyhelminthes	
		Dugesia sp.	17.9 [j]
		Polycellis niger/tenius	19.9 [j]
Mollusca		**Mollusca**	
Marisa cornuarietis	0.016 [d]	*Physa fontinalis*	10.2 [j]
		Planorbis contortis	6.0 [j]
		Annelida	

Chronic[a] Taxonomic group/*species*	NOEC/EC10 (µg/L)	Acute[a] Taxonomic group/*species*	L(E)C50 (µg/L)
		Tubifex sp.	11.0 [j]
Crustacea		**Crustacea**	
		Ceriodaphnia dubia	10.8
Daphnia magna	1.1 [e]	*Daphnia magna*	15.8 [k]
		Daphnia pulex	13.8
		Gammarus pulex	10.8 [j]
Insecta		**Insecta**	
Chironomus riparius	0.52 [f]	*Anopheles stephensi*	42 [l]
		Cloeon dipterum	144.5 [j]
		Endochironomus albipennis	259.2 [j]
Pisces		**Pisces**	
		Cyprinus carpio	36.2
Oncorhynchus mykiss	0.18	*Oncorhynchus mykiss*	23.9 [m]
Oryzias latipes	0.00043 [g]	*Oryzias latipes*	50.5
Phoxinus phoxinus	0.2 [h]		
Pimephales promelas	0.154 [i]	*Pimephales promelas*	6.4 [n]
Amphibia			
Pelophylax lessonae/esculenta	0.11		

[a] For detailed information see Appendix 1
[b] Endpoint based on combined low ad high concentration range
[c] Most sensitive endpoint: growth rate
[d] Most sensitive endpoint: spawning mass production
[e] Most sensitive endpoint: mortality; geometric mean of 0.73, 0.86 and 2.2 µg/L
[f] Most sensitive endpoint: development rate
[g] Most sensitive endpoint: larval survival
[h] Most sensitive endpoint: mortality and morphological deformities
[i] Most sensitive exposure period: 183d
[j] Most sensitive exposure period: 96h
[k] Most sensitive exposure period: 48h
[l] Most sensitive stadium: 2nd instar and most toxic species TPT-Ac
[m] Geometric mean of 14.3 and 40.1 µg/L
[n] Geometric mean of 9.2, 6.8, 5.1, 5.7 and 5.7 µg/L

Table 28. Triphenyltin: selected marine toxicity data for ERL derivation for the triphenyltin ion

Chronic[a] Taxonomic group/*species*	NOEC/EC10 (µg/L)	Acute[a] Taxonomic group/*species*	L(E)C50 (µg/L)
		Bacteria	
		Vibrio fischeri	40 [d]
Algae			
Pavlova lutheri	0.04		
Mollusca			
Nucella lapillus	0.15		
Crustacea			
Rhithropanopeus harrisii	9.5		
Echinodermata			
Anthocidaris crassispina	245 [b]		
Paracentrotus lividus	1.0		
Ophiodermata brevispina	0.011 [c]		
		Pisces	
		Chasmichthys dolichognathus	19 [e]

[a] For detailed information see Appendix 1
[b] Most sensitive endpoint: embryo development
[c] Geometric mean of 0.009 and 0.0126 µg/L
[d] Geometric mean of 18 and 87 µg/L
[e] Geometric mean of 17, 20 and 20 µg/L

4.3.2 Treatment of fresh- and saltwater toxicity data

According to Lepper (2005), data from fresh- and saltwater tests should be pooled unless there are indications that sensitivity of species differs between the two compartments. For organic pesticides and metals, however, data should be kept separated. In the upcoming revision of the guidance for deriving water quality standards with the context of the WFD (EU, 2000), this will be changed and data for pesticides will be pooled as well, unless there is evidence that this is not justified. Triphenyltin is an organometalloid and a pesticide as well, and the speciation of the compound may vary among different water types. The present data, however, do not indicate that there is a consistent difference between freshwater and marine species with respect to their sensitivity towards triphenyltin. Therefore, the combined dataset will be used for derivation of risk limits. This is consistent with the use of combined datasets for derivation of water quality standards for di- and tributyltin compounds by ICPR and European Commission, respectively (ICBR, 2009, EC, 2005).

4.3.3 Derivation of the MPC_{water}

4.3.3.1 Derivation of the $MPC_{water, eco}$

In Van Herwijnen et al. (2012), an MPC for fresh surface water of 0.23 ng/L has been derived on the basis of the HC5 of a Species Sensitivity Distribution (SSD) with an assessment factor of 10. This MPC is adopted as the $MPC_{fw, eco}$. For the saltwater environment the same MPC of 0.23 ng/L has been derived because three additional taxonomic groups are covered in the dataset. This MPC is adopted as the $MPC_{sw, eco}$.

4.3.3.2 Derivation of the $MPC_{water, secpois}$

In Van Herwijnen et al. (2012), it is concluded that the risk through secondary poisoning is covered by the $MPC_{water, hh food}$ of 1.4 ng/L. Since this value is higher than the $MPC_{fw, eco}$ and $MPC_{sw, eco}$, it can be concluded that the risk of secondary poisoning is covered by the MPCs for direct toxicity.

4.3.3.3 Selection of the MPC_{water}

Since the risk of secondary poisoning is covered by the MPCs for direct toxicity, these MPC will set the MPC_{fw} and MPC_{sw} at 0.23 ng/L.

4.3.4 Derivation of the $MAC_{water, eco}$

In Van Herwijnen et al. (2012), a $MAC_{fw, eco}$ and $MAC_{sw, eco}$ have been derived by application of an SSD over the acute toxicity data. An assessment factor of 10 has been applied on the HC5 of 4.7 μg/L and an additional assessment factor for the saltwater environment is considered not necessary because the chronic data indicate that marine species are not more sensitive than freshwater species. The $MAC_{fw, eco}$ and $MAC_{sw, eco}$ are both 0.47 μg/L, but are considered irrelevant in view of the large difference with the chronic toxicity data.

4.3.5 Derivation of the SRC_{water}

4.3.5.1 Derivation of the $SRC_{water, eco}$

In Van Herwijnen et al. (2012), the $SRC_{water, eco}$ is calculated as the HC50 from the SSD: 0.40 μg/L.

4.3.5.2 Derivation of the $SRC_{water, secpois}$

For derivation of the $SRC_{water, secpois}$ the most relevant endpoints are selected and presented in Table 29. Because for guinea pigs, hamsters, mice, rabbits and rats more than one study is available, the most appropriate MPC_{oral} for these organisms was selected. According to the INS-Guidance (section 3.1.4.2, point 2, last lines), it is recommended in this case 'to use the most sensitive endpoint divided by the appropriate assessment factor (*i.e.* the factor implied by the study with the longest test duration)'. A full overview is given in Appendix 4. The MPC_{oral} per species is calculated, applying the appropriate assessment factor (see Table 29).

Table 29. Toxicity data for birds and mammals

Species	Duration of exposure	NOEC diet [mg/kg fd]	AF for conversion to chronic	AF for correction to laboratory feed	$MPC_{oral, mammal}$ $MPC_{oral, bird}$ [mg/kg fd]	Reference
Birds						
Bobwhite quail	20/21 weeks	5.2*	1	3	1.7	EC (1996a, 1996b)
Japanese quail	6 weeks	2.9	1	3	1.0	Grote et al. (2006)
Mallard Duck	20 weeks	2.9	1	3	1.0	EC (1996a, 1996b)
Mammals						
guinea pig	90 days	4.8	3	3	0.53	Verschuuren et al. (1966)
hamster	10 days during gestation	39	3	3	4.3	US EPA (1982)
mouse	80 weeks	4.8	1	3	1.6	US EPA (1989)
rabbit	12 days during gestation	3.2	3	3	0.36	US EPA (1987d)
rat	2 years/2 generations	4.8	1	3	1.6	US EPA (1989, 1991b, 1987c, 1991a)

* Geometric mean of 9.5 and 2.9 mg/kg_{diet} of two similar studies.

The geometric mean of the MPC_{oral} values in Table 29 is 1.3 mg/kg_{food}. With this value, the BCF of 3500 L/kg and the BMF1 of 3.7, the $SRC_{water, secpois}$ is 0.10 µg/L.

4.3.5.3 Selection of the SRC_{water}

The SRC_{water} is determined by the lowest value; this is the $SRC_{water, secpois}$ of 0.10 µg/L.

The SRC_{water} is valid for the fresh- and saltwater environment.

4.4 Risk limits for groundwater

The $MPC_{gw, eco}$ and $SRC_{gw, eco}$ are equal to the $MPC_{fw, eco}$ and $SRC_{fw, eco}$ and are 0.23 ng/L and 0.40 µg/L respectively.

4.5 Risk limits for sediment

In Van Herwijnen et al. (2012), risk limits for sediment have been derived for triphenyltin. These risk limits are taken over in this report where available.

4.5.1 *Sediment toxicity data*

The sediment toxicity data selected in Van Herwijnen et al. (2012) are given in Table 30.

Table 30. Triphenyltin: selected sediment toxicity data for ERL derivation for the triphenyltin ion

Chronic [a]	**NOEC/EC10**	**Acute** [a]	**L(E)C50**
Taxonomic group/*species*	**(mg/kg$_{dwt}$)**	**Taxonomic group/***species*	**(mg/kg$_{dwt}$)**
Mollusca		**Insecta**	
Potamopyrgus antipodarum	0.22×10^{-3}	*Chironomus riparius*	2.8 [b]
Ephoron virgo	0.023 [c]		

[a] for detailed information see Appendix 2
[b] geometric mean of 3.10 mg/kg$_{dwt}$ and 2.49 mg/kg$_{dwt}$
[c] Most sensitive endpoint: survival

4.5.2 *Derivation of the MPC$_{sediment}$*

In Van Herwijnen et al. (2012), an MPC for fresh water sediment of 2.2 ng/kg$_{dwt}$ has been derived on the basis of the chronic NOEC for the mollusc *Potamopyrgus antipodarum* and an assessment factor of 100. This MPC is adopted as the MPC$_{sediment, fw}$. For the saltwater environment the same MPC of 2.2 ng/kg$_{dwt}$ has been derived because it was concluded that marine species are not more sensitive to triphenyltin than freshwater species.

4.5.3 *Derivation of the SRC$_{sediment, eco}$*

In Van Herwijnen et al. (2012), the SRC$_{sediment, eco}$ was based on the two NOECs available, which was lower than derived through equilibrium partitioning or than the only acute value divided by 10. The SRC$_{sediment, eco}$ is 2.2 µg/kg$_{dwt}$ for standard Dutch sediment with 10% OM and is valid for the marine and the freshwater environment.

4.6 Risk limits for soil

4.6.1 *Soil toxicity data*

Selected soil toxicity data are given in Table 31, details on these endpoints are tabulated in Appendix 3.

Table 31. Triphenyltin: selected soil toxicity data for ERL derivation

Chronic **Taxonomic group**	**NOEC/EC10 (mg/kg$_{dwt}$)**	**Acute** **Taxonomic group**	**L(E)C/50 (mg/kg$_{dwt}$)**
Microbial processes		**Microbial processes**	
Acetate mineralization	910	Acetate mineralization	3810
Annelida		**Annelida**	
Eisenia andrei	9.1	*Eisenia fetida*	29
Collembola			
Folsomia candida	37.4 [a]		

[a] Geometric mean of 191.0 mg/kg$_{dwt}$, 10.5 mg/kg$_{dwt}$, 56.1 mg/kg$_{dwt}$ and 17.3 mg/kg$_{dwt}$ for four clones representing the variety of sensitivity in the environment. The values are expressed for Dutch standard soil.

4.6.2 *Derivation of the MPC_{soil}*

4.6.2.1 Derivation of the $MPC_{soil, eco}$

Chronic soil toxicity data are available for decomposers (*acetate mineralization*) and consumers (*Eisenia andrei* and *Folsomia candida*). With chronic data representing two trophic levels, an assessment factor of 50 can be applied to lowest value of 9.1 mg/kg. This results in an $MPC_{soil, eco}$ of 0.18 mg/kg_{dwt} for Dutch standard soil with 10% organic matter.

4.6.2.2 Derivation of $MPC_{soil, secpois}$

A BCF has been reported higher than 100 L/kg; therefore, secondary poisoning is triggered. An $MPC_{soil, secpois}$ can be calculated from the worst-case $MPC_{oral, min}$ of 0.019 mg/kg_{fd} (Van Herwijnen et al., 2012) with the method as described in Van Vlaardingen and Verbruggen (2007). A BCF for earthworms is not available and the use of a QSAR on the basis of the log K_{ow} is considered not appropriate because of the bioaccumulation characteristics of triphenyltin. Therefore, the use of the BCF for fish is considered the best alternative. Additional factors for bioaccumulation are not considered necessary because the BMF2 is set 1 (see Van Herwijnen et al. (2012)), The log K_{ow} value used was 3.53 and the log K_{oc} value used was 4.0 as used in (Van Herwijnen et al., 2012). The Henry value used was 4.3 $Pa/m^3/mol$ as the geometric mean of the values for the three TPT-species. With these values, the calculated $MPC_{soil, secpois}$ is 4.0 $\mu g/kg_{dwt}$ for Dutch standard soil with 10% organic matter.

4.6.2.3 Selection of the MPC_{soil}

Since the $MPC_{soil, secpois}$ is lower than the $MPC_{soil, eco}$, it will set the MPC_{soil}: 4.0 $\mu g/kg_{dwt}$ for Dutch standard soil with 10% organic matter.

4.6.3 *Derivation of the SRC_{soil}*

4.6.3.1 Derivation of the $SRC_{soil, eco}$

The $SRC_{soil, eco}$ is calculated as the geometric mean of the chronic toxicity data in Table 31. The $SRC_{soil, eco}$ is 68 mg/kg_{dwt} for Dutch standard soil with 10% organic matter.

4.6.3.2 Derivation of the $SRC_{soil, secpois}$

For the $SRC_{eco, oral}$, the geometric mean of 1.3 mg/kg_{food} as determined above is used for calculation of the $SRC_{soil, secpois}$. With use of the log K_{oc} value of 4.0 and the BCF for fish of 3500 L/kg, the calculated $SRC_{soil, secpois}$ is 0.24 mg/kg_{dwt} for Dutch standard soil with 10% organic matter.

4.6.3.3 Selection of the SRC_{soil}

The SRC_{soil} is set by the lowest value, this is the $SRC_{soil, secpois}$ of 0.24 mg/kg_{dwt} for Dutch standard soil with 10% organic matter.

4.6.4 *Geometric mean of MPC and SRC*

The geometric mean of the MPC_{soil} and SRC_{soil} is 31 $\mu g/kg_{dwt}$.

5 Conclusions

In this report, the risk limits Maximum Permissible Concentration for ecosystems (MPC_{eco}), Maximum Acceptable Concentration (MAC_{eco}) and Serious Risk Concentration for ecosystems (SRC_{eco}) are derived for three organotin compounds in surface water, groundwater and soil. The MPC values are considered to be protective for direct toxicity and exposure through secondary poisoning. The risk for humans consuming fishery product or food from contaminated soil is not considered in these values. The ERLs that were obtained are summarised in Table 32.

Table 32. Derived MPC_{eco}, MAC_{eco} and SRC_{eco} values for dibutyltin-, tributultin- and triphenyltin-cations

Compartiment	dibutyltin	tributyltin	triphenyltin
Surface water			
MPC_{fw} (µg/L)	0.15	0.2×10^{-3}	0.23×10^{-3}
MPC_{sw} (µg/L)	0.15	0.2×10^{-3}	0.23×10^{-3}
$MAC_{fw, eco}$ (µg/L)	0.30	1.5×10^{-3}	0.47
$MAC_{sw, eco}$ (µg/L)	0.15	0.2×10^{-3}	0.47
SRC_{water} (µg/L)	16	26×10^{-3}	0.10
Groundwater			
$MPC_{gw, eco}$ (µg/L)	0.15	0.2×10^{-3}	0.23×10^{-3}
$SRC_{gw, eco}$ (µg/L)	50	46×10^{-3}	0.40
Sediment [a]			
$MPC_{sediment, eco}$ (µg/kg_{dwt})	0.37×10^{3}	0.01 [c]	2.2×10^{-3}
$SRC_{sediment, eco}$ (µg/kg_{dwt})	123×10^{3}	27	2.2
Soil [b]			
MPC_{soil} (mg/kg_{dwt})	0.37	2.3×10^{-6}	4.0×10^{-3}
SRC_{soil} (mg/kg_{dwt})	28	52×10^{-3}	0.24
geometric mean of MPC_{soil} and SRC_{soil} (mg/kg_{dwt})	3.2	0.35×10^{-3}	0.031

n.d. = not derived

[a] Sediment values are expressed for Dutch standard sediment with 10% organic matter.

[b] Soil values are expressed for Dutch standard soil with 10% organic matter.

[c] This value should be considered as a worst-case estimate.

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List of abbreviations

ADI	Acceptable Daily Intake
BCF	Bioconcentration Factor
EC_x	Concentration at which x% effect is observed
EQS	Environmental Quality Standard
ERL	Environmental Risk Limit
INS	International and National Environmental Quality Standards for Substances in the Netherlands
LC50	Concentration at which 50% mortality is observed
MAC_{eco}	Maximum Acceptable Concentration for ecosystems
$MAC_{fw, eco}$	Maximum Acceptable Concentration for ecosystems in freshwater
$MAC_{sw, eco}$	Maximum Acceptable Concentration for ecosystems in the saltwater compartment
Marine species	Species that are representative for marine and brackish water environments and that are tested in water with salinity > 0.5‰.
MPC	Maximum Permissible Concentration
MPC_{eco}	Maximum Permissible Concentration for ecosystems (based on ecotoxicological data)
MPC_{fw}	Maximum Permissible Concentration in freshwater
MPC_{sw}	Maximum Permissible Concentration in the saltwater compartment
$MPC_{fw, eco}$	Maximum Permissible Concentration in freshwater based on ecotoxicological data
$MPC_{sw, eco}$	Maximum Permissible Concentration in the saltwater compartment based on ecotoxicological data
$MPC_{fw, secpois}$	Maximum Permissible Concentration in freshwater based on secondary poisoning
$MPC_{sw, secpois}$	Maximum Permissible Concentration in the saltwater compartment based on secondary poisoning
NOEC	No Observed Effect Concentration
NOAEL	No Observed Adverse Effect Level
SRC_{eco}	Serious Risk Concentration for ecosystems
$SRC_{fw, eco}$	Serious risk concentration for freshwater ecosystems
$SRC_{sw, eco}$	Serious risk concentration for saltwater ecosystems
TDI	Tolerable Daily Intake
TGD	Technical Guidance Document
WFD	Water Framework Directive (2000/60/EC)

Appendix 1. Data on K_{oc} studies

Table A1.1. Brief summaries of available K_{oc} studies for dibutyltin

Log K_{oc}	brief summary	Ri	ref
5.29	Determined from desorption from a natively contaminated freshwater sediment using a sediment:water ratio of 1:2000 and an equilibrium time of 72 h at pH 7.4; analysis in water and sediment. Log K_d = 4.05, %oc = 5.8.	2	Berg et al. (2001)
5.37	Determined from desorption from a natively contaminated marine sediment using a high sediment:water ratio of 1:2000 and an equilibrium time of 72 h at pH 7.4; analysis in water and sediment. Log K_d = 3.95, %oc = 3.7.	2	Berg et al. (2001)
4.88	Determined from desorption from a natively contaminated marine sediment using a high sediment:water ratio of 1:2000 and an equilibrium time of 72 h at pH 7.4; analysis in water and sediment. Log K_d = 3.38, %oc = 3.2.	2	Berg et al. (2001)
5.47	Calculated from in situ distribution (porewater) in natively contaminated freshwater sediment, pH 7.3; analysis in water and sediment. Log K_d = 4.11, %oc = 4.4.	2	Berg et al. (2001)
5.78	Calculated from in situ distribution (porewater) in natively contaminated freshwater sediment; pH 7.3; analysis in water and sediment. Log K_d = 4.44, %oc = 4.6.	2	Berg et al. (2001)
5.51	Determined from desorption from a natively contaminated marine sediment using a sediment:water ratio of 1:18 (based on wet weight sediment) and an equilibrium time of 42 days + 1 day for settling before analysis; pH 7.7; analysis in water and sediment. Log K_d = 4.07, %oc = 3.7.	2	Brändli et al. (2009)
4.73	Geometric mean of K_{oc} based on desorption for six treated contaminated sediments obtained using a sediment:water ratio of 1:2 and an equilibrium time of 6 h; analysis in water only; pH unknown. Considered unreliable because of the short equilibrium time and lack of analysis in sediment	3	Cornelis et al. (2006)
3.39	Value from test with soil, determined with data from graph with Freundlich sorption curve; soil:water ratio of 1:50; pH 6.32; equilibrium time of 24 h; analysis in water only. % sorbed 86%; %oc = 6.56; log Kf = 2.21 and 1/n = 1.2. Considered unreliable because 1/n > 1.1.	3	Cukrowska et al. (2010)
3.73	Value from test with soil, determined with data from graph with Freundlich sorption curve; soil:water ratio of 1:50; pH 6.52; equilibrium time of 24 h; analysis in water only. % sorbed 83%; %oc = 3.79; log Kf = 2.31 and 1/n = 1.05.	2	Cukrowska et al. (2010)
3.21	Value from test with soil, determined with data from graph with Freundlich sorption curve; soil:water ratio of 1:50; pH 6.92; equilibrium time of 24 h; analysis in water only. % sorbed 47%; %oc = 2.81, log Kf = 1.66 and 1/n = 0.90.	2	Cukrowska et al. (2010)
3.59	Value from test with soil, determined with data from graph with Freundlich sorption curve; soil:water ratio of 1:50; pH 6.68; equilibrium time of 24 h; analysis in water only. % sorbed 38%; %oc = 1.89, log Kf = 1.86 and 1/n = 0.89.	2	Cukrowska et al. (2010)
5.09	Value based on Kf for Freundlich sorption on marine sediment; sediment:water ratio of 1:50; equilibrium time of 24 h; pH 7.57; analysis in water and sediment. %oc = 1.23; log Kf = 3.18 and 1/n = 0.98.	2	Dai et al. (2002)
5.20	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only. Fraction sorbed 47%. Calculated from data in graph using Freundlich; %oc = 0.06; log Kf = 1.98 and 1/n = 0.857. The fraction of oc in the soil is considered too low to determine a reliable K_{oc}.	3	Hoch et al. (2003)
4.08	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only. Fraction sorbed 39%. Calculated from data in graph using Freundlich; %oc = 0.25; log Kf = 1.48 and 1/n = 1.01.	2	Hoch et al. (2003)
5.36	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only. Fraction sorbed 37%. Calculated from data in graph using Freundlich; %oc = 0.16, log Kf = 2.57 and 1/n = 0.532. Considered unreliable because 1/n < 0.7	3	Hoch et al. (2003)
4.78	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only. Fraction sorbed 20%. Calculated from data in graph using Freundlich; %oc = 0.06; log Kf = 1.56 and 1/n = 0.816. The fraction of oc in the soil is considered too low to determine a reliable K_{oc}.	3	Hoch et al. (2003)

Log K_{oc}	brief summary	Ri	ref
4.31	Experiment performed with soil with pH 4.7; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only. Fraction sorbed 99.8%. Calculated from data in graph using Freundlich; %oc = 44.3, log Kf = 3.96 and 1/n = 3.96. Considered unreliable because of 1/n > 1.1 and fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
4.10	Experiment performed with soil with pH 5.5; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only. Fraction sorbed 92.7%. Calculated from data in graph using Freundlich; %oc = 1.55, log Kf = 2.29 and 1/n = 2.30. Considered unreliable because of 1/n > 1.1	3	Huang and Matzner (2004)
3.54	Experiment performed with soil with pH 3.8+ soil:water ratio of 1:50+ equilibrium time of 24 h+ analysis of water only. Fraction sorbed 98.0%. Calculated from data in graph using Freundlich, %oc = 31.4, log Kf = 3.04 and 1/n = 0.887. Considered unreliable because fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
4.74	Experiment performed with soil with pH 3.9+ soil:water ratio of 1:50 equilibrium time of 24 h; analysis of water only. Fraction sorbed 98.0%. Calculated from data in graph using Freundlich; %oc = 4.82, log Kf = 3.42 and 1/n = 1.01. Considered unreliable because fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
	In situ determination of distribution in natively contaminated marine harbour sediment; analysis in water and sediment; no details on sediment reported and %oc unknown. Reported log K_d values range from 3.8 to 4.4 for two locations and two timepoints.	4	Stang and Seligman (1987)
3.4	Experiment performed with sediment and artificial seawater with salinity of 15‰ and pH 8.0; sediment:water ratio of 1:45; equilibrium time of 18-24 h; analysis in water only. Fraction sorbed 32%. %oc = 0.84; log Kf = 1.33 and 1/n = 0.969.	2	Sun et al. (1996)

Table A1-2. K_{oc} values for tributyltin from public literature

Log K_{oc}	species	brief summary	Ri	ref
4.6	TBTCl	Determined on sediment from potentially polluted area according to ASTM method. K_d determined from intercept of the adsorption isotherm based on the Freundlich equation. Standard Freundlich parameters (Kf and 1/n) not reported. Equilibrium time 12 h. Equilibrium time shown to be suitable with initial test. Log K_d 3.63; %oc = 12.1.	2	Bangkedphol et al. (2009)
4.2	TBTCl	Determined on sediment from potentially polluted area according to ASTM method. K_d determined from intercept of the adsorption isotherm based on the Freundlich equation. Standard Freundlich parameters (Kf and 1/n) not reported. Equilibrium time 12 h. Equilibrium time shown to be suitable with initial test. Log K_d 3.48; %oc = 17.42.	2	Bangkedphol et al. (2009)
5.5	?	Determined from desorption from a natively contaminated marine sediment using a sediment:water ratio of 1:18 (based on wet weight sediment) and an equilibrium time of 42 days + 1 day for settling before analysis; pH 7.7; analysis in water and sediment. Log K_d = 4.07 %oc = 3.7.	2	Brandli et al (2009)
5.1	?	Determined on marine sediment using a sediment:water ratio of 1:25 and an equilibrium time of 42 days + 1 day for settling before analysis; pH7.7 analysis in water and sediment. Log K_d = 3.35; %oc = 1.98.	2	Brandli et al (2009)
4.5	TBTCl	Determined on natural pristine sediment with varying salinity (5 and 30‰) and pH (4, 6 and 8) of the water; the reported values are the geometric mean for six scenarios; sediment:water ratio = 1:10; equilibrium time 24 h at 20°C; %oc: 4.8; analysis of water only; considered unreliable because of high fraction sorbed in most cases and lack of analysis in sediment; log K_d = 3.19.	3	Burton et al. (2004)
4.1	TBTCl	Determined on natural pristine sediment with varying salinity (5 and 30‰) and pH (4, 6 and 8) of the water; the reported values are the geometric mean for six scenarios; sediment:water ratio = 1:10; equilibrium time 24 h at 20°C; %oc: 2.6; analysis of water only; log K_d = 2.48.	2	Burton et al. (2004)
3.8	TBTCl	Determined on natural pristine sediment with varying salinity (5 and 30‰) and pH (4, 6 and 8) of the water; the reported values are the geometric mean for six scenarios; sediment:water ratio = 1:10; equilibrium time 24 h at 20°C; %oc: 0.2; analysis of water only; log K_d = 1.09.	2	Burton et al. (2004)
3.2	TBTCl	Determined on natural pristine sediment with varying salinity (5 and 30‰) and pH (4, 6 and 8) of the water; the reported values are the geometric mean for six scenarios; sediment:water ratio = 1:10; equilibrium time 24 h at 20°C; %oc: 2.2; analysis of water only; log K_d = 1.56.	2	Burton et al. (2004)
4.7	TBTCl	Geometric mean of K_{oc} based on desorption for six treated contaminated sediments obtained using a sediment:water ratio of 1:2 and an equilibrium time of 6 h; analysis in water only; pH unknown. Considered unreliable because of the short equilibrium time and lack of analysis in sediment	3	Cornelis et al. (2006)
4.7	TBTCl	Value based on Kf for Freundlich sorption on marine sediment; sediment:water ratio of 1:50; equilibrium time of 24 h; pH 7.57; analysis in water and sediment; %oc = 1.23; log Kf = 2.76 and 1/n = 0.90.	2	Dai et al. (2002)
4.9	TBTCl	Value based on Kf for Freundlich sorption on marine sediment; geometric mean for two different water phases tested (salinity/pH: 22.6‰/7.24 and 30.8‰/7.57); sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water and sediment; %oc = 2.54; log Kf = 3.29 and 1/n = 0.92 for both tests.	2	Dai et al. (2002)
5.0	TBTCl	Value based on Kf for Freundlich sorption on marine sediment; geometric mean for two different water phases tested(salinity/pH: 3.0‰/6.58 and 30.8‰/7.57); sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water and sediment; %oc = 2.62; log Kf = 3.37 and 1/n = 0.90 for both tests.	2	Dai et al. (2002)
5.0	TBTCl	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only; fraction sorbed 60%. %oc = 0.06; log K_d = 1.80. The fraction of OC in the soil is considered too low to determine a reliable K_{oc}.	3	Hoch et al. (2003)
4.3	TBTCl	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only; fraction sorbed 36%. %oc = 0.16; log K_d = 1.46.	2	Hoch et al. (2003)
5.0	TBTCl	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only; fraction sorbed 59%. %oc = 0.06; log K_d = 1.77. The fraction of OC in the soil is considered too low to determine a reliable K_{oc}.	3	Hoch et al. (2003)
4.4	TBTCl	Experiment performed with sediment and artificial seawater with salinity of 32‰ and pH 8; sediment:water ratio of 1:50; equilibrium time of 24 h; analysis in water only fraction sorbed 63%. %oc = 0.25; log K_d = 1.85.	2	Hoch et al. (2003)

Log K_{oc}	species	brief summary	Ri	ref
4.5	?	Experiment performed with soil with pH 4.7; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only; fraction sorbed 99.6%. %oc = 44.3; log K_d = 4.18. Considered unreliable because fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
4.3	?	Experiment performed with soil with pH 3.7; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only; fraction sorbed 99.1%. %oc = 31.4; log K_d = 3.75. Considered unreliable because fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
4.4	?	Experiment performed with soil with pH 3.9; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only; fraction sorbed 96.5%. %oc = 4.82; log K_d = 3.12. Considered unreliable because fraction sorbed very high while no analysis of solid phase	3	Huang and Matzner (2004)
3.1	?	Experiment performed with soil with pH 5.50; soil:water ratio of 1:50; equilibrium time of 24 h; analysis of water only; fraction sorbed 37.2%. %oc = 1.55; log K_d = 1.33.	2	Huang and Matzner (2004)
4.2	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.09; OC = 6.9%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.0	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.42; OC = 4.0%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.1	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.92; OC = 6.2%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.4	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 2.39; OC = 0.8%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
5.0	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.91; OC = 2.2%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.6	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.92; OC = 3.5%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.6	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.22; OC = 4.7%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.5	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.25; OC = 5.8%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.5	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.23; OC = 5.5%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.5	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.07; OC = 4.6%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
5.0	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.03; OC = 2.6%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.2	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.95; OC = 5.9%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)

Log K_{oc}	species	brief summary	Ri	ref
4.9	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 3.71; OC = 2.0%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.7	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.39; OC = 5.2%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.6	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.23; OC = 5.2%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
4.7	TBTCl	Experiment performed with marine sediment, natural filtered seawater and 14C labelled TBT; sediment:water ratio 1:500;equilibrium time 24 h; analysis in both water and sediment; log K_d = 4.30; OC = 4.8%; K_{oc} recalculated from K_d and fraction OC	2	Langston and Pope (1995)
3.2	TBTCl	Experiment performed with sediment and artificial seawater with salinity of 15‰ and pH 8.0; sediment:water ratio of 1:45; equilibrium time of 18-24 h; analysis in water only. %oc = 0.84; log Kf = 1.07 and 1/n = 0.359; study considered unreliable becauseof low 1/n.	2	Sun et al. (1996)
5.3	TBTCl	Experiment performed with sediment and artificial seawater; sediment:water ratio 1:33 and 1:333; equilibrium time of 24 h; analysis in water only. %oc = 4.2; log K_d = 3.91.	2	Unger et al. (1987)
4.7	TBTCl	Experiment performed with sediment and artificial seawater; sediment:water ratio 1:33 and 1:333; equilibrium time of 24 h; analysis in water only. %oc = 2.9; log K_d = 3.11.	3	Unger et al. (1987)
5.3	TBTCl	Experiment performed with sediment and artificial seawater; sediment:water ratio 1:33 and 1:333; equilibrium time of 24 h; analysis in water only. %oc = 0.34; log K_d = 2.78.	3	Unger et al. (1987)
4.1	TBTCl	Experiment performed with sediment and artificial seawater; sediment:water ratio 1:33 and 1:333; equilibrium time of 24 h; analysis in water only. %oc = 0.90; log K_d = 2.04.	2	Unger et al. (1987)

Appendix 2. Detailed soil toxicity data for tributyltin

Table A2.1. Acute toxicity of tributyltin (and tributyltin-oxide) for soil organisms

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg_{dwt}]	Result test soil TBT-ion [mg/kg_{dwt}]	Result stand. soil [mg/kg_{dwt}]	Result stand. soil TBT-ion [mg/kg_{dwt}]	Ri	Notes	Reference
Macrophyta																			
Avena sativa		sandy soil	Y	TBT-Cl		5.8	3.9	8.2		14 d	EC50	biomass		452		1159	2	1	Hund-Rinke and Simon (2005)
Avena sativa		silty soil	Y	TBT-Cl		6.1	2.9	14.6		14 d	EC50	biomass		553		1907	2	1	Hund-Rinke and Simon (2005)
Avena sativa		loamy soil	Y	TBT-Cl		5.4	5.6	31.5		14 d	EC50	biomass		687		1227	2	1	Hund-Rinke and Simon (2005)
Brassica rapa		sandy soil	Y	TBT-Cl		5.8	3.9	8.2		14 d	EC50	biomass		25		64	2	1	Hund-Rinke and Simon (2005)
Brassica rapa		silty soil	Y	TBT-Cl		6.1	2.9	14.6		14 d	EC50	biomass		16		55	2	1	Hund-Rinke and Simon (2005)
Brassica rapa		loamy soil	Y	TBT-Cl		5.4	5.6	31.5		14 d	EC50	biomass		39		70	2	1	Hund-Rinke and Simon (2005)
Annelida																			
Enchytraeus albidus		sandy loam	N	TBT-O	97.8	5.5	3.9	6	20	48 h	EC50	avoidance	95		244		3	2	Amorim et al. (2008)
Eisenia fetida		sandy soil	N	TBT-Cl		5.5	1.7	3.6	20	48 h	EC50	avoidance		2.3		13.5	2	3	Hund-Rinke et al. (2005)
Eisenia fetida		loamy soil	N	TBT-Cl		5.4	5.6	31.5	20	48 h	EC50	avoidance		2.6		4.6	2	3	Hund-Rinke et al. (2005)

Notes
1 Test performed according to ISO guidelines; organic matter content calculated from reported organic carbon content; 14-d aging period at 4°C after contamination; measured concentrations within 25% of nominal; endpoint based on nominal concentrations; endpoint expressed as TBT-ion confirmed by author.
2 Estimated value, no dose-response pattern, no significant difference from control.
3 Endpoint expressed as TBT-ion confirmed by author.

Table A2.2. Chronic toxicity of tributyltin (and tributyltin-oxide) for soil organisms

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Bacteria																			
Escherichia coli		sandy loam	Y	TBT		6.32	3.8	11.5	25	15 min	EC20	luminescence	11.2		29.5		3	1	Trott et al. (2007)
Pseudomonas fluorescens		sandy loam	Y	TBT		6.32	3.8	11.5	25	15 min	EC20	luminescence	21.5		56.6		3	1	Trott et al. (2007)
Vibrio fischeri		sandy loam	Y	TBT		6.32	3.8	11.5	22	10 min	EC20	luminescence	9.41		24.8		3	1	Trott et al. (2007)
Macrophyta																			
Brassica rapa	Seeds	OECD	N	TBT-O		6	8	8	23	35 d	EC50	biomass	535.5	519.4	669.4	649.3	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	OECD	N	TBT-O		6	8	8	23	35 d	EC10	biomass	169.2	164.1	211.5	205.2	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	OECD	N	TBT-O		6	8	8	23	35 d	NOEC	biomass	222.2	215.5	277.8	269.4	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	silty clay loam	N	TBT-O		4.9	4	29.7	23	35 d	EC50	biomass	30.7	29.8	76.8	74.4	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	silty clay loam	N	TBT-O		4.9	4	29.7	23	35 d	EC10	biomass	3.9	3.8	9.8	9.5	2	2,4,5	Rombke et al. (2007)
Brassica rapa	Seeds	silty clay loam	N	TBT-O		4.9	4	29.7	23	35 d	NOEC	biomass	< 24.7	< 24.0	< 61.8	< 59.9	2	2,4,5	Rombke et al. (2007)
Brassica rapa	Seeds	loamy sand	N	TBT-O		5.5	1.6	3.82	23	35 d	EC50	biomass	19.2	18.6	120.0	116.4	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	loamy sand	N	TBT-O		5.5	1.6	3.82	23	35 d	EC10	biomass	4.3	4.2	26.9	26.1	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	loamy sand	N	TBT-O		5.5	1.6	3.82	23	35 d	NOEC	biomass	8.2	8.0	51.3	49.7	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		5.2	4.5	24.9	23	35 d	EC50	biomass	54.9	53.3	42.7	41.4	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		5.2	4.5	24.9	23	35 d	EC10	biomass	42.3	41.0	9.6	9.3	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		5.2	4.5	24.9	23	35 d	NOEC	biomass	24.7	24.0	18.2	17.7	2	2,3,4	Rombke et al. (2007)
Brassica rapa	Seeds	Loam	N	TBT-O		5.8	5.7	25.9	23	35 d	EC50	biomass	189.2	183.5	96.3	93.4	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	Loam	N	TBT-O		5.8	5.7	25.9	23	35 d	EC10	biomass	54	52.4	74.2	72.0	2	2,4	Rombke et al. (2007)
Brassica rapa	Seeds	loam	N	TBT-O		5.8	5.7	25.9	23	35 d	NOEC	biomass	24.7	24.0	43.3	42.0	2	2,4	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		7.4	3.8	22.5	23	35 d	EC50	biomass	10.7	10.4	497.9	483.0	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		7.4	3.8	22.5	23	35 d	EC10	biomass	2.6	2.5	142.1	137.8	2	2,4,6	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		7.4	3.8	22.5	23	35 d	NOEC	biomass	2.7	2.6	65.0	63.1	2	2,4,6	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		6.6	2.8	15	23	35 d	EC50	biomass	75.9	73.6	38.2	37.1	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		6.6	2.8	15	23	35 d	EC10	biomass	43.3	42.0	9.3	9.0	2	2,4,6	Rombke et al. (2007)
Brassica rapa	Seeds	silt loam	N	TBT-O		6.6	2.8	15	23	35 d	NOEC	biomass	24.7	24.0	9.6	9.4	2	2,4,6	Rombke et al. (2007)
Brassica rapa	Seeds	sandy loam	N	TBT-O		6.1	4.6	6.84	23	35 d	EC50	biomass	149.3	144.8	165.0	160.1	2	2	Rombke et al. (2007)
Brassica rapa	Seeds	sandy loam	N	TBT-O		6.1	4.6	6.84	23	35 d	EC10	biomass	34.7	33.7	94.1	91.3	2	2,4	Rombke et al. (2007)
Brassica rapa	Seeds	sandy loam	N	TBT-O		6.1	4.6	6.84	23	35 d	NOEC	biomass	24.71	24.0	53.7	52.1	2	2,4	Rombke et al. (2007)
Annelida																			
Eisenia fetida		sandy	Y	TBT-Cl		5.5	1.7	3.6		56 d	EC50	reproduction		1.3		7.6	2	8	Hund-Rinke and Simon (2005)
Eisenia fetida		silty	Y	TBT-Cl		6.1	2.9	14.6		56 d	EC50	reproduction		3		10.3	2	8	Hund-Rinke and Simon (2005)

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Eisenia fetida		loamy	Y	TBT-Cl		5.4	5.6	31.5		56 d	EC50	reproduction		2.7		4.8	2	8	Hund-Rinke and Simon (2005)
Eisenia fetida		sandy	N	TBT-Cl		5.5	1.7	3.6		56 d	EC10	reproduction		0.26		1.5	3	9	Hund-Rinke et al. (2005)
Eisenia fetida		loamy	N	TBT-Cl		5.4	5.6	31.5		56 d	EC10	reproduction		0.47		0.84	3	9	Hund-Rinke et al. (2005)
Eisenia andrei	Adult	OECD	N	TBT-O		6	8	8	18-22	28 d	LC50	mortality	56.2	54.5	70.3	68.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	OECD	N	TBT-O		6	8	8	18-22	28 d	LC10	mortality	37	35.9	46.3	44.9	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	OECD	N	TBT-O		6	8	8	18-22	56 d	EC10	reproduction	3.9	3.8	4.9	4.7	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	OECD	N	TBT-O		6	8	8	18-22	56 d	NOEC	reproduction	3.2	3.1	4.0	3.9	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	LC50	mortality	8.6	8.3	21.5	20.9	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	LC10	mortality	6	5.8	15.0	14.6	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	56 d	EC10	reproduction	2.1	2.0	5.3	5.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	56 d	NOEC	reproduction	1	1.0	2.5	2.4	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	LC50	mortality	15.3	14.8	58.8	57.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	LC10	mortality	4.4	4.3	16.9	16.4	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	56 d	EC10	reproduction	0.3	0.3	1.2	1.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	56 d	NOEC	reproduction	0.3	0.3	1.2	1.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	LC50	mortality	8.5	8.2	53.1	51.5	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	LC10	mortality	4.5	4.4	28.1	27.3	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	56 d	EC10	reproduction	0.03	0.0	0.2	0.2	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	56 d	NOEC	reproduction	< 0.3	< 0.3	< 1.2	< 1.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	LC50	mortality	10.4	10.1	23.1	22.4	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	LC10	mortality	6.5	6.3	14.4	14.0	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	56 d	EC10	reproduction	2.4	2.3	5.3	5.2	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	56 d	NOEC	reproduction	1	1.0	2.2	2.2	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	LC50	mortality	12.6	12.2	22.1	21.4	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	LC10	mortality	6	5.8	10.5	10.2	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	loam	N	TBT-O		5.8	5.7	25.9	18-22	56 d	EC10	reproduction	0.6	0.6	1.1	1.0	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	loam	N	TBT-O		5.8	5.7	25.9	18-22	56 d	NOEC	reproduction	0.3	0.3	0.5	0.5	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	LC50	mortality	12.6	12.2	33.2	32.2	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	LC10	mortality	6	5.8	15.8	15.3	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	56 d	EC10	reproduction	2.4	2.3	6.3	6.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	56 d	NOEC	reproduction	1	1.0	2.6	2.6	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	LC50	mortality	12.3	11.9	43.9	42.6	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	LC10	mortality	8.8	8.5	31.4	30.5	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		6.6	2.8	15	18-22	56 d	EC10	reproduction	2.5	2.4	8.9	8.7	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	silt loam	N	TBT-O		6.6	2.8	15	18-22	56 d	NOEC	reproduction	1	1.0	3.6	3.5	2	2	Rombke et al. (2007)

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Eisenia andrei	Adult	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	LC50	mortality	15	14.6	32.6	31.6	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	LC10	mortality	8.3	8.1	18.0	17.5	2	2,7	Rombke et al. (2007)
Eisenia andrei	Adult	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	56 d	EC10	reproduction	1	1.0	2.2	2.1	2	2	Rombke et al. (2007)
Eisenia andrei	Adult	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	56 d	NOEC	reproduction	1	1.0	2.2	2.1	2	2	Rombke et al. (2007)
Collembola																			
Folsomia candida	juvenile	sandy soil	Y	TBT-Cl		5.5	1.7	3.6		28 d	EC50	reproduction		22		129	2	8	Hund-Rinke and Simon (2005)
Folsomia candida	juvenile	silty soil	Y	TBT-Cl		6.1	2.9	14.6		28 d	EC50	reproduction		11		37.9	2	8	Hund-Rinke and Simon (2005)
Folsomia candida	juvenile	loamy soil	Y	TBT-Cl		5.4	5.6	31.5		28 d	EC50	reproduction		66		118	2	8	Hund-Rinke and Simon (2005)
Folsomia candida	juv., 10-12 d	OECD soil	N	TBT-O		6	8	8	18-22	28 d	LC50	mortality	345.8	335.4	432.3	419.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	OECD soil	N	TBT-O		6	8	8	18-22	28 d	LC10	mortality	57.9	56.2	72.4	70.2	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	OECD soil	N	TBT-O		6	8	8	18-22	28 d	EC10	reproduction	17.7	17.2	22.1	21.5	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	OECD soil	N	TBT-O		6	8	8	18-22	28 d	NOEC	reproduction	10	9.7	12.5	12.1	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	LC50	mortality	113.1	109.7	282.8	274.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	LC10	mortality	10.9	10.6	27.3	26.4	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	EC10	reproduction	9.9	9.6	24.8	24.0	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silty clay loam	N	TBT-O		4.9	4	29.7	18-22	28 d	NOEC	reproduction	10	9.7	25.0	24.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	LC50	mortality	20.7	20.1	79.6	77.2	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	LC10	mortality	7.8	7.6	30.0	29.1	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	EC10	reproduction	15.6	15.1	60.0	58.2	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12d	loamy sand	N	TBT-O		3.8	2.6	5.1	18-22	28 d	NOEC	reproduction	10	9.7	38.5	37.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.1	8.7	4.67	18-22	28 d	LC50	mortality	127.1	123.3	146.1	141.7	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.1	8.7	4.67	18-22	28 d	LC10	mortality	65.1	63.1	74.8	72.6	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.1	8.7	4.67	18-22	28 d	EC10	reproduction	28.5	27.6	32.8	31.8	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		3.1	8.7	4.67	18-22	28 d	NOEC	reproduction	10	9.7	11.5	11.1	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	LC50	mortality	91.9	89.1	574.4	557.1	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	LC10	mortality	10.2	9.9	63.8	61.8	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	EC10	reproduction	9.8	9.5	61.3	59.4	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loamy sand	N	TBT-O		5.5	1.6	3.82	18-22	28 d	NOEC	reproduction	10	9.7	62.5	60.6	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	LC50	mortality	806.5	782.3	1792.2	1738.5	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	LC10	mortality	51.2	49.7	113.8	110.4	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	EC10	reproduction	145.8	141.4	324.0	314.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		5.2	4.5	24.9	18-22	28 d	NOEC	reproduction	100	97.0	222.2	215.6	2	2,3,4	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	LC50	mortality	109.2	105.9	191.6	185.8	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	LC10	mortality	10.7	10.4	18.8	18.2	2	2,7	Rombke et al. (2007)

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Folsomia candida	juv., 10-12 d	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	EC10	reproduction	72	69.8	126.3	122.5	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	loam	N	TBT-O		5.8	5.7	25.9	18-22	28 d	NOEC	reproduction	31.6	30.7	55.4	53.8	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	LC50	mortality	66.1	64.1	173.9	168.7	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	LC10	mortality	35.2	34.1	92.6	89.9	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	EC10	reproduction	20.8	20.2	54.7	53.1	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		7.4	3.8	22.5	18-22	28 d	NOEC	reproduction	10	9.7	26.3	25.5	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	LC50	mortality	134	130.0	478.6	464.2	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	LC10	mortality	60.5	58.7	216.1	209.6	2	2,7	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	EC10	reproduction	19.8	19.2	70.7	68.6	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	silt loam	N	TBT-O		6.6	2.8	15	18-22	28 d	NOEC	reproduction	10	9.7	35.7	34.6	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	LC50	mortality	137.2	133.1	298.3	289.3	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	LC10	mortality	14.5	14.1	31.5	30.6	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	EC10	reproduction	27.8	27.0	60.4	58.6	2	2	Rombke et al. (2007)
Folsomia candida	juv., 10-12 d	sandy loam	N	TBT-O		6.1	4.6	6.84	18-22	28 d	NOEC	reproduction	10	9.7	21.7	21.1	2	2	Rombke et al. (2007)

Notes

1 Tests were performed with soil extracts and water:soil ratio for the extraction is not reported; it is unclear how this relates to the actual toxicity in soil; the used chemical form of TBT is not reported.
2 OM content calculated from reported OC content; 16:8 h L:D
3 LOEC higher than EC50
4 EC10 considered more relevant for risk limit derivation than NOEC
5 LOEC is lowest concentration tested
6 LOEC close to EC50
7 LC10 values not the paper; provided by the author through personal communication
8 Test performed according to ISO guidelines; organic matter content calculated from reported organic carbon content; 14-d aging period at 4°C after contamination; measured concentrations within 25% of nominal; endpoint based on nominal concentrations; endpoint expressed as TBT-ion confirmed by author
9 Test according to ISO; 27% reduction at 0.3 mg/kg but no statistics available, authors use 50% inhibition of reproduction as threshold; EC10 estimated from original data, but only three concentrations tested, which makes estimation not reliable; endpoint expressed as TBT-ion confirmed by author.

Table A2.3. Toxicity of tributyltin (and tributyltin-oxide) to soil microbial processes and enzyme activity

Process/activity	**Soil type**	**A**	**Test comp.**	**Purity [%]**	**pH**	**o.m. [%]**	**Clay [%]**	**T [°C]**	**Exp. time**	**Crit.**	**Test endpoint**	**Result test soil [mg/kg$_{dwt}$]**	**Result test soil TBT-ion [mg/kg$_{dwt}$]**	**Result stand. Soil [mg/kg$_{dwt}$]**	**Result stand. soil TBT-ion [mg/kg$_{dwt}$]**	**Ri**	**Notes**	**Reference**
Microbial processes																		
Basal respiration	sandy soil	Y	TBT-Cl		5.5	1.7	3.6			EC50	Respiration rate		>1000		> 5882	2	1,2,3	Hund-Rinke and Simon (2005)
Basal respiration	silty soil	Y	TBT-Cl		6.1	2.9	14.6			EC50	Respiration rate		>1000		> 3448	2	1,2,3	Hund-Rinke and Simon (2005)
Basal respiration	loamy soil	Y	TBT-Cl		5.4	5.6	31.5			EC50	Respiration rate		>1000		> 1786	2	1,2,3	Hund-Rinke and Simon (2005)
Substrate induced respiration	sandy soil	Y	TBT-Cl		5.5	1.7	3.6			EC50	Respiration rate		>1000		> 5882	2	1,2,4	Hund-Rinke and Simon (2005)
Substrate induced respiration	silty soil	Y	TBT-Cl		6.1	2.9	14.6			EC50	Respiration rate		>1000		> 3448	2	1,2,4	Hund-Rinke and Simon (2005)
Substrate induced respiration	loamy soil	Y	TBT-Cl		5.4	5.6	31.5			EC50	Respiration rate		>1000		> 1786	2	1,2,4	Hund-Rinke and Simon (2005)
Potential nitrification	sandy soil	Y	TBT-Cl		5.5	1.7	3.6		6 h	EC50	Ammonium oxidation		11		65	2	1	Hund-Rinke and Simon (2005)
Potential nitrification	silty soil	Y	TBT-Cl		6.1	2.9	14.6		6 h	EC50	Ammonium oxidation		64		221	2	1	Hund-Rinke and Simon (2005)
Potential nitrification	loamy soil	Y	TBT-Cl		5.4	5.6	31.5		6 h	EC50	Ammonium oxidation		156		279	2	1	Hund-Rinke and Simon (2005)
Respiration	luvisol	Y	TBT-Cl		7.88	4.9		18	64 d	NOEC	CO2 evolution	6.7	6.0	14	12	2	5	Rossel and Tarradellas (1991)
Enzymatic activity																		
Dehydrogenase	luvisol	Y	TBT-Cl		7.88	4.9		18	64 d	NOEC	dehydrogenase activity	6.7	6.0	14	12	2	5	Rossel and Tarradellas (1991)
ATP content	luvisol	Y	TBT-Cl		7.88	4.9		18	64 d	NOEC	ATP content	6.7	6.0	14	12	2	6	Rossel and Tarradellas (1991)
Esterase activity	luvisol	Y	TBT-Cl		7.88	4.9		18	64 d	NOEC	esterase activity	67	60	137	122	2	6	Rossel and Tarradellas (1991)

Notes

1 Test performed according to ISO guidelines; organic matter content calculated from reported organic carbon content; 14-d aging period at 4°C after contamination; measured concentrations within 25% of nominal; endpoint based on nominal concentrations; endpoint expressed as TBT-ion confirmed by author.

2 Actual exposure time not reported.

3 Exposure is as long as period of measurement: 'the respiration rates should be measured until constant rates are obtained'.

4 Exposure lasted from addition of growth substrate untill 'respiration curve reaches its peak and respiration rates are declining'.

5 After contamination, soil moisture content was kept at 23% (pF 2.1) for 64 days, after which soil was air-dried to 1.5% and remoistened on day 120; results of the first phase are used only; organic matter content calculated from reported organic carbon content. Endpoint based on initial measured concentration recalculated to time weighted average; reduction in TBT concentration during exposure period of 64 days about 40-80% half-life = 70 d; unclear if endpoint is expressed as TBT-ion or TBT-Cl; the latter is presumed.

6 Organic matter content calculated from reported organic carbon content. Endpoint based on initial measured concentration recalculated to time weighted average; reduction in TBT concentration during exposure period of 64 d about 40-80%; half life = 70 d; unclear if endpoint is expressed as TBT-ion or TBT-Cl; the latter is presumed.

Appendix 3. Detailed soil toxicity data for triphenyltin

Table A3.1. Acute toxicity of triphenyltin for soil organisms

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg_{dwt}]	Result test soil TBT-ion [mg/kg_{dwt}]	Result stand. soil [mg/kg_{dwt}]	Result stand. soil TBT-ion [mg/kg_{dwt}]	Ri	Notes	Reference
Annelida																			
Eisenia fetida	2 months old	artificial	N	TPT-Ac			10	20		7 d	LC50	mortality	362	310	362	310	2	1	EU-DAR (1996a, 1996b)
Eisenia fetida	2 months old	artificial	N	TPT-Ac			10	20		14 d	LC50	mortality	128	110	1128	110	2	1	EU-DAR (1996a, 1996b)
Eisenia fetida	2 months old	artificial	N	TPT-Ac			10	20		14 d	NOEC	weight	10.7	9.2	10.7	9.2	2	1	EU-DAR (1996a, 1996b)
Eisenia fetida	> 2 months old, 338-479 mg/10 worms	artificial	N	TPT-OH	40.7		10	20		7 d	LC50	mortality	30.5	29	30.5	29	2	2	EU-DAR (1996a, 1996b)
Eisenia fetida	> 2 months old, 338-479 mg/10 worms	artificial	N	TPT-OH	40.7		10	20		14 d	LC50	mortality	30.5	29	30.5	29	2	2	EU-DAR (1996a, 1996b)

Notes

1 Performed according to OECD 207 guideline; orig ref: Fischer 1990B not available

2 Performed according to OECD 207; TPT applied as SC formulation 500 g TPT-OH L; endpoints in abstract reported for SC-formulation; therefore corrected to a.s. using a density of 1.23 g/ml as given in the DAR; orig ref: Fischer 1990 not available

Table A3.2. Chronic toxicity of triphenyltin for soil organisms

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Bacteria																			
Escherichia coli		sandy loam	Y	TPT		6.32	3.8	11.5	25	15 min	EC20	luminescence	24.8		65.3		3	1	Trott et al. (2007)
Pseudomonas fluorescens		sandy loam	Y	TPT		6.32	3.8	11.5	25	15 min	EC20	luminescence	41.2		108.4		3	1	Trott et al. (2007)
Vibrio fischeri		sandy loam	Y	TPT		6.32	3.8	11.5	22	10 min	EC20	luminescence	11.5		30.3		3	1	Trott et al. (2007)
Annelida																			
Eisenia andrei				TPT					22	28 d	LC50	mortality	27				3	2	Visser and Linders (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	EC50	cocoon production	28	25.48	28	25.48	2	3	Van Gestel et al (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	NOEC	cocoon production	10	9.1	10	9.1	2	3	Van Gestel et al (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	LC50	mortality	57	51.87	57	51.87	2	3	Van Gestel et al (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	NOEC	cocoon hatchability	≥32	≥29	≥32	≥29	2	3	Van Gestel et al (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	NOEC	reproduction	10	9.1	10	9.1	2	3	Van Gestel et al (1992)
Eisenia andrei	8.5-15.5 weeks, 170-582 mg	OECD	Y	TPT-Cl	>99	6	10	20	20	21 d	NOEC	growth	10	9.1	10	9.1	2	3	Van Gestel et al (1992)
Eisenia fetida		mixture	N	TPT			> 50		20	28 d	EC50	body mass	3.9		≤ 0.78		3	4	Zsombok et al. (1997)
Collembola																			
Folsomia candida	Norwich clone	OECD	Y	TPT-OH		6	10	20	20	35 d	LC50	mortality	> 2323	> 2207	> 508	> 483	2	5	Crommentuijn et al. (1995)
Folsomia candida	Brunoy clone	OECD	Y	TPT-OH		6	10	20	20	35 d	LC50	mortality	1152	1094.4	126	119.7	2	5	Crommentuijn et al. (1995)
Folsomia candida	Haren clone	OECD	Y	TPT-OH		6	10	20	20	35 d	LC50	mortality	1546	1468.7	226	214.7	2	5	Crommentuijn et al. (1995)
Folsomia candida	Roggebotzand clone	OECD	Y	TPT-OH		6	10	20	20	35 d	LC50	mortality	1115	1059.3	127	120.7	2	5	Crommentuijn et al. (1995)
Folsomia candida	Norwich clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC50	reproduction	508	482.6	508	482.6	2	5	Crommentuijn et al. (1995)
Folsomia candida	Brunoy clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC50	reproduction	126	119.7	126	119.7	2	5	Crommentuijn et al. (1995)
Folsomia candida	Haren clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC50	reproduction	226	214.7	226	214.7	2	5	Crommentuijn et al. (1995)

Species	Species properties (age, sex)	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Folsomia candida	Roggebotzand clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC50	reproduction	127	120.7	127	120.7	2	5	Crommentuijn et al. (1995)
Folsomia candida	Norwich clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC10	reproduction	508	482.6	201	191.0	2	5	Crommentuijn et al. (1995)
Folsomia candida	Brunoy clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC10	reproduction	126	119.7	11	10.5	2	5	Crommentuijn et al. (1995)
Folsomia candida	Haren clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC10	reproduction	226	214.7	59.1	56.1	2	5	Crommentuijn et al. (1995)
Folsomia candida	Roggebotzand clone	OECD	Y	TPT-OH		6	10	20	20	35 d	EC10	reproduction	127	120.7	18.2	17.3	2	5	Crommentuijn et al. (1995)

Notes

1 Tests were performed with soil extracts and water:soil ratio for the extraction is not reported; it is unclear how this relates to the actual toxicity in soil; the used chemical form of TPT is not reported.

2 From original reference, it is known that the TPT was tested in combination with another active ingredient (maneb).

3 Actual concentration at 0.32 mg/kg was 0.56 mg/kg at the start and 0.34 mg/kg at the end of the test; result based on nominal.

4 The worms were exposed in a mixture of peaty marshland soil and horse manure at a ratio of 1:1. The OM concent of the marshland soil is unknown; the used chemical form of TPT is not reported.

5 Actual concentrations at 300 and 3000 mg/kg nominal were 282 and 2320 mg/kg at the start, and 132 and 1604 mg/kg at the end (47 and 69% of nominal); metabolites diphenyltin and monophenyltin were present; endpoint based on estimated actual initial concentrations, obtained from regression between nominal and actual.

Table A3.3. Toxicity of triphenyltin to soil microbial processes and enzyme activity

Process/activity	Soil type	A	Test comp.	Purity [%]	pH	o.m. [%]	Clay [%]	T [°C]	Exp. time	Crit.	Test endpoint	Result test soil [mg/kg$_{dwt}$]	Result test soil TBT-ion [mg/kg$_{dwt}$]	Result stand. soil [mg/kg$_{dwt}$]	Result stand. soil TBT-ion [mg/kg$_{dwt}$]	Ri	Notes	Reference
Microbial processes																		
Acetate mineralization	sandy	N	TPT-OH	97	4.4	1	0.4	10	2 d	EC50	mineralization	1700	1619	17000	16190	2	1	Van Beelen and Fleuren-Kemila (1993)
Acetate mineralization	sandy	N	TPT-OH	97	4.4	1	0.4	10	2 d	EC10	mineralization	640	610	6400	6100	2	1	Van Beelen and Fleuren-Kemila (1993)
Acetate mineralization	sandy	N	TPT-OH	97	4.4	1	0.4	10	2 d	IC50	mineralization rate	400	381	4000	3810	2	2	Van Beelen and Fleuren-Kemila (1993)
Acetate mineralization	sandy	N	TPT-OH	97	4.4	1	0.4	10	2 d	IC10	mineralization rate	96	91	960	910	2	2	Van Beelen and Fleuren-Kemila (1993)
Nitrification	loamy	N	TPT-Ac		7.6	1.6	11		120 h	NOEC	nitrification rate	> 10	> 8.6	> 62.5	> 53.5	4	3	Visser and Linders (1992)
Respiration	loamy sand	N	TPT-OH	40.7					56 d	NOEC	respiration rate	< 0.267	< 0.254			3	4,5,6	EU-DAR (1996a, 1996b)
Respiration	clay silt	N	TPT-OH	40.7					56 d	NOEC	respiration rate	≥2.67	≥2.54			3	4,5,7	EU-DAR (1996a, 1996b)
Nitrogen metabolism	clay silt	N	TPT-OH	40.7					28 d	NOEC	nitrification	≥2.67	≥2.54			3	4,5,8	EU-DAR (1996a, 1996b)
Nitrogen metabolism	loamy sand	N	TPT-OH	40.7					56 d	NOEC	nitrification	≥2.67	≥2.54			3	4,5,9	EU-DAR (1996a, 1996b)
Nitrogen metabolism	clay silt	N	TPT-OH	40.7					56 d	NOEC	nitrification	≥2.67	≥2.54			3	4,5,9	EU-DAR (1996a, 1996b)

Notes

1 Endpoint represents effect on final percentage mineralized, taking into account that mineralization by the un-intoxicated part of the microflora continues; endpoint expressed as TPT-OH confirmed by author; organic matter content calculated from reported organic carbon content.
2 Endpoint represents effect on initial mineralization rate, without taking into account that mineralization by the un-intoxicated part of the microflora continues; endpoint expressed as TPT-OH confirmed by author.
3 Original reference not available.
4 Unknown if substance is sprayed or mixed into the soil.
5 TPT-OH applied as formulation.
6 Effect of 2.3% compared to the control after 56 days; orig ref: Baedelt 1991A not available.
7 No effect in comparison with the control after 56 days; orig ref: Baedelt 1991A not available.
8 Orig ref: Baedelt 1991B not available.
9 Orig ref: Baedelt 1991C not available.

Appendix 4. Detailed toxicity of triphenyltin to birds and mammals

Table A4.1. Toxicity of triphenyltin to mammals and birds

Species	Properties	Test compound	Purity	Application route	Vehicle	Test duration	Exposure time	Criterion	Test endpoint	Criterion – oral dosing	Criterion - diet	Criterion – diet – TPT+	Ri	Notes	Reference
	(age, sex)		[%]							[mg/kg$_{b.w.}$/d]	[mg/kg$_{diet}$]	[mg/kg$_{diet}$]			
Mammals															
Dog		TPT-OH		diet		52 weeks	52 weeks	NOAEL	toxicology	≥ 0.6	≥ 24	≥ 23	4	2	EC (1996a, 1996b)
Dog	beagel, 4-6 months, males 5.1-11.8 kg, female 5.4-9.6 kg	TPT-OH	97.2	diet		52 weeks	52 weeks	NOEC	overall		≥ 18	≥ 17	2	4	US EPA (1987b)
Guinea pig		TPT-OH		diet		13 weeks	13 weeks	NOAEL	body weight gain	< 0.2	< 4	< 3.8	4	2	EC (1996a, 1996b)
Guinea pig		TPT-Ac		diet		13 weeks	13 weeks	NOAEL	body weight gain	< 0.2	< 4	< 3.6	4	2	EC (1996a, 1996b)
Guinea pig	male and female	TPT-OH	97.1	diet		90 days	90 days	NOEC	growth		10	9.5	2		Verschuuren et al. (1966)
Guinea pig	male and female	TPT-Ac	95-96	diet		90 days	90 days	NOEC	growth		5	4.8	2		Verschuuren et al. (1966)
Hamster	pregnant female	TPT-OH		gavage		15 days	day 5-14 of gestation	NOAEL	maternal toxicity/embryo toxicity	5.08	42	40	4		WHO (1999)
Hamster	pregnant female	TPT-OH		gavage		15 days	day 5 to 15 of gestation	NOAEL	maternal toxicity	4.91	41	39	2	4	US EPA (1982)
Mouse	female, 50-60 days, 30-35 g	TPT-OH	97.3	gavage	corn oil	18 days	day 6 17 of gestation	NOAEL	embyo toxicity	< 3.75	< 31	< 30	2		Sarpa et al. (2007)
Mouse	pregnant female	TPT-OH	97.3	gavage	corn oil	40 days	day 6 to 17 of gestation	NOAEL	maternal body weight gain/embryo toxicity/litter viability	7.5	62	59	2		Delgado Filho et al. (2011)
Mouse	male and female	TPT-OH	97.2			80 weeks	80 weeks	NOEC	growth		5	4.8	4		WHO (1999)
Mouse	5 weeks, males 26-30 g, females 21-25 g	TPT-OH	97.2	diet		13 weeks	13 weeks	NOEC	body weight gain/food consumption		≥ 100	≥ 95	2	4	US EPA (1986)
Mouse	male and female	TPT-OH	97.2	diet		80 weeks	80 weeks	NOEC	mortality		20	19	2	4	US EPA (1989)
Mouse	male and female	TPT-OH	97.2	diet		80 weeks	80 weeks	NOEC	body weight		5	4.8	2	4	US EPA (1989)
Rabbit	pregnant female	TPT-Ac		gavage		29 days	day 6 to 18 of gestation	NOAEL	maternal toxicity/embryo toxicity	0.32	11	9.1	4		WHO (1999)

Species	Properties	Test compound	Purity	Application route	Vehicle	Test duration	Exposure time	Criterion	Test endpoint	Criterion – oral dosing	Criterion - diet	Criterion – diet – TPT$^+$	Ri	Notes	Reference
	(age, sex)		[%]							[mg/kg$_{b.w.}$/d]	[mg/kg$_{diet}$]	[mg/kg$_{diet}$]			
Rabbit	pregnant female	TPT-OH		gavage		29 days	day 6 to 18 of gestation	NOAEL	maternal toxicity	0.1	3.3	3.2	4		WHO (1999)
Rabbit	male, 7 months, 2.9kg	TPT-Cl	99	orally		12 weeks	12 weeks	NOAEL	sperm production	< 0.5	< 17	< 15	3	1	Yousef et al (2010)
Rabbit		TPT-OH		gavage				NOAEL	maternal toxicity	0.1	3.3	3.1	4	2	EC (1996a, 1996b)
Rabbit		TPT-OH		gavage				NOAEL	embryotoxicity	0.3	10	9.5	4	2	EC (1996a, 1996b)
Rabbit	pregnant female	TPT-OH		gavage	1% aqueous carboxymethyl-cellulose	29 days	day 6 to 18 of gestation	NOAEL	embryotoxicity	1	33	32	2	4	US EPA (1987d)
Rabbit	pregnant female	TPT-OH		gavage	1% aqueous carboxymethyl-cellulose	29 days	day 6 to 18 of gestation	NOAEL	maternal toxicity	0.1	3.3	3.2	2	4	US EPA (1987d)
Rabbit	male, 6-11 weeks	TPT-Ac		diet		70 days	70 days	NOEC	body weight gain		75	71	2		Dacasto et al. (1994)
Rat	neonatal	TPT-Ac		gavage	milk+tween		day 2 to 29 of age	NOAEL	body weight	3	60	51	2		Mushak et al. (1982)
Rat	pregnant female	TPT-OH		gavage	corn oil	28 days	day 6 to 15 of gestation	NOAEL	body weight	2.8	56	53	2	4	US EPA (1991a)
Rat	pregnant female	TPT-Cl		gavage	olive oil	20 days	day 0 to 3 of gestation	NOAEL	body weight gain/food consumption	< 3.1	< 62	< 59	2		Ema et al. (1997)
Rat	pregnant female	TPT-Cl		gavage	olive oil	20 days	day 4 to 6 of gestation	NOAEL	body weight gain/food consumption	< 6.3	< 126	< 120	2		Ema et al. (1997)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	20 days	day 10 to 12 of gestation	NOAEL	embryo toxicity	6.3	126	115	2		Ema et al. (1999)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	20 days	day 13 to 15 of gestation	NOAEL	embryo toxicity	6.3	126	115	2		Ema et al. (1999)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	20 days	day 10 to 12 of gestation	NOAEL	maternal body weight gain	< 6.3	< 126	< 115	2		Ema et al. (1999)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	20 days	day 13 to 15 of gestation	NOAEL	maternal body weight gain	< 6.3	< 126	< 115	2		Ema et al. (1999)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	20 days	day 7 to 9 of gestation	NOAEL	maternal body weight gain/embryo toxicity	3.1	62	56	2		Ema et al. (1999)
Rat		TPT-OH		diet		2 gen		NOAEL	maternal body weight gain/litter growth and viability	1.4-1.7	28-34	27-32	4	2	EC (1996a, 1996b)
Rat	pregnant female	TPT-OH				20 days	day 6-15 of gestation	NOAEL	maternal toxicity	1	20	19	4		WHO (1999)

Species	Properties	Test compound	Purity	Application route	Vehicle	Test duration	Exposure time	Criterion	Test endpoint	Criterion – oral dosing	Criterion - diet	Criterion – diet – TPT$^+$	Ri	Notes	Reference
	(age, sex)		[%]							[mg/kg$_{b.w.}$/d]	[mg/kg$_{diet}$]	[mg/kg$_{diet}$]			
Rat	pregnant female	TPT-OH	97.3		corn oil	20 days	day 5 to 19 of gestation	NOAEL	maternal toxicity	2.8	22.4	21	2	4	US EPA (1982)
Rat	pregnant female, 200 g	TPT-Ac		gavage	aqueous suspension	21 days	day 6 to 15 of gestation	NOAEL	maternal toxicity	5	100	86	2		Giavini et al. (1980)
Rat	pregnant female	TPT-OH	97.1	gavage	corn oil	20 days	day 6 to 15 of gestation	NOAEL	maternal toxicity	1	20	19	2	4	US EPA (1985)
Rat	pregnant female	TPT-OH		gavage	corn oil	20 days	day 5 to 15 of gestation	NOAEL	maternal toxicity/embryo toxicity	5	100	95	3	5	US EPA (1991a)
Rat	pregnant female	TPT-OH		gavage		20 days	day 7 to 20 of gestation	NOAEL	maternal toxicity/embryo toxicity	4	80	76	2	4	US EPA (1991a)
Rat	10-11 weeks, 225-334 g	TPT-OH	97.5	gavage	corn oil	85 days	day 6 to 20 of gestation	NOAEL	maternal toxicity/reproduction	2.5	50	48	2	4	US EPA (2005)
Rat	pregnant female	TPT-Cl	98	gavage	olive oil	9 days	first three days of gastation	NOAEL	pregnancy rate	< 4.7	< 94	< 86	2		Ema and Miyawaki (2001)
Rat	pregnant female	TPT-Cl		gavage	olive oil	20 days	day 0 to 3 of gestation	NOAEL	reproduction	3.1	62	59	2		Ema et al. (1997)
Rat	pregnant female	TPT-Cl		gavage	olive oil	20 days	day 4 to 6 of gestation	NOAEL	reproduction	6.3	126	120	2		Ema et al. (1997)
Rat	pregnant female	TPT-Ac		gavage	olive oil	20 days	day 7-17 of gestation	NOAEL	embryo toxicity	3	60	57	2		Noda et a. (1991)
Rat	male and female	TPT-Ac		gavage	5% tween solution	5 weeks	5 weeks	NOAEL	mortality	5	100	95	3	7	Attahiru et a. (1991)
Rat	pregnant female	TPT-OH		gavage	corn oil	20 days	day 6 to 15 of gestation	NOAEL	maternal toxicity	< 13	< 260	< 247	3	1	Chernoff et al. (1990)
Rat	male, 3-4 weeks	TPT-OH	> 96	diet		3 weeks	3 weeks	NOAEL	body weight		≥25	≥24	2	1	Vos et al. (1984)
Rat	4-5 weeks, males 92-117 g, females 71-95 g	TPT-OH	97.2	diet		17 weeks	13 weeks	NOEC	body weight gain		20	19	2	4	US EPA (1986)
Rat	male and female, 5 weeks	TPT-OH	97	diet		2 years	2 years	NOEC	body weight, food and water consumption		5	4.8	2	4	US EPA (1989)
Rat	44 days, males 167-232 g, females 132-177 g	TPT-OH	96	diet		91 days	91 days	NOEC	bodyweight/food consumption		20	19	2	4	US EPA (2004)
Rat	male and female	TPT-OH		diet		2 gen		NOEC	mortality		5	4.8	4		WHO (1999)
Rat	male and female	TPT-OH	100	diet		2 years	2 years	NOEC	mortality		5	4.8	2	4	US EPA (1991b)
Rat		TPT-OH	97.2	diet		2 gen		NOEC	reproduction		5	4.8	2	4	US EPA (1987c)
Rat	male and female	TPT		diet		1 gen		NOEC	reproduction		50	48	4	6	US EPA (1991a)
Rat	male and female	TPT-OH		diet		2 gen		NOEC	reproduction		5	4.8	2	4	US EPA (1991a)

Species	Properties	Test compound	Purity	Application route	Vehicle	Test duration	Exposure time	Criterion	Test endpoint	Criterion – oral dosing	Criterion - diet	Criterion – diet – TPT^+	Ri	Notes	Reference
	(age, sex)		**[%]**							**[$mg/kg_{b.w.}/d$]**	**[mg/kg_{diet}]**	**[mg/kg_{diet}]**			
Rat	male and female	TPT-OH	97.1	diet		90 days	90 days	NOEC	growth		25	24	2		Verschuuren et al. (1966)
Rat	male and female	TPT-Ac	95-96	diet		90 days	90 days	NOEC	growth		10	9.5	2		Verschuuren et al. (1966)
Rat	male and female, 21 days	TPT-OH		diet		90 days	90 days	NOEC	mortality		< 1000	< 950	2		Winek et al. (1978)
Rat	male and female, 2-3 months	TPT-OH		diet		90 days	90 days	NOEC	mortality		100	95	2	9	Winek et al. (1978)
Rat	male	TPT-Cl	>98	diet		2 weeks	2 weeks	NOEC	body weight		15	14	2		Snoeij et al. (1985)
Rat	male, 4-5 weeks	TPT-OH	tg	diet		99 days	99 days	NOEC	body weight/food consumption		100	95	2		Gaines and Kimbrough (1968)
Rat	male, 8-9 weeks	TPT-OH	tg	diet/gavage	peanut oil	276 days	276 days	NOEC	male fertility		50	48	2	10	Gaines and Kimbrough (1968)
Sheep	male, 5-6 months	TPT-Ac		gelatin capsule		70 days	70 days	NOAEL	body weight gain	≥ 7.5			2	8	Dacasto et al. (1994)
Birds															
Bobwhite quail	12 days	TPT-OH	97.1	diet	corn oil	8 days	5 days	LC50	mortality		253	240	2	3	EC (1996a, 1996b)
Bobwhite quail	20 weeks	TPT-OH	97.2	diet		21 weeks	21 weeks	NOEC	reproduction		10	9.5	2	3	EC (1996a, 1996b)
Bobwhite quail	18 weeks	TPT-OH	97.9	diet		20 weeks	20 weeks	NOEC	reproduction		3	2.9	2	3	EC (1996a, 1996b)
Japanese quail		TPT-OH	> 99	diet		6 weeks	6 weeks	NOEC	egg production/hatching		3	2.9	2		Grote et al. (2006)
Malard duck	16 weeks	TPT-OH	97.2	diet		21 weeks	21 weeks	NOEC	reproduction		> 10	> 9.5	2	3	EC (1996a, 1996b)
Malard duck	18 weeks	TPT-OH	97.9	diet		25 weeks	20 weeks	NOEC	reproduction		3	2.9	2	3	EC (1996a, 1996b)
Mallard duck	14 days	TPT-OH	96	diet	corn oil	8 days	5 days	LC50	mortality		533	506	2	3	EC (1996a, 1996b)
Mallard duck	10 days	TPT-OH formulation	40%	diet		5 days	5 days	LC50			168.4	160	2	4	US EPA (1987a)

Notes
1 Only one concentration tested.
2 Summary in DAR not available; data from overview.
3 Summary in the DAR sufficient to evaluate the study.
4 Summary in EPA document sufficient to evaluate the study.
5 Considered irreliable because of an unexplained inconsistency between data in the report.
6 Summary in EPA document too brief to evaluate the study.
7 Unclear if reported mortality is related to the substance.
8 No conversion factor to food available.
9 Other effects than mortality not reported.
10 During the mating period, the animals were dosed through a gavage.

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